UNIV. OF
TORONTO
LIBRARY

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/proceedings190201inst

THE INSTITUTION

OF

MECHANICAL ENGINEERS.

ESTABLISHED 1847.

PROCEEDINGS.

1902.

Parts 1-2.

63599
11/11/04

PUBLISHED BY THE INSTITUTION,
Storey's Gate, St. James's Park, Westminster, S.W.

The right of Publication and of Translation is reserved.

TJ
1
I4
1902
pt. 1-2

CONTENTS.

1902.

PARTS 1-2.

PAGE
List of Past-Presidents iv
List of Officers v
Articles and By-Laws vii
PROCEEDINGS, 17TH JANUARY—
  Nomination of Candidates for Council 2
  Election of New Members 3
  Transferences 6
PROCEEDINGS, 31ST JANUARY.—Business 8
  "Modern Machine Methods"; by H. F. L. Orcutt (Plates 1-8) . 9
GRADUATES' MEETING, 10TH FEBRUARY—
  "Gas-Engine Developments"; by T. H. Beare 113
PROCEEDINGS, ANNUAL GENERAL MEETING, 21ST FEBRUARY—
  Transferences 137
  Annual Report 138
  Presentation of Graduates' Prizes 161
  Election of Officers 162
  Appointment of Auditor 164
SPECIAL MEETING.—Alteration of Rules 165
"Triple-Expansion Steam-Engine Trial"; by C. J. Hobbs 169
Memoirs 195
SPECIAL MEETING, 10TH MARCH—
  Confirmation of Alteration of Rules 203
PROCEEDINGS, 21ST MARCH—
  Decease of Mr. Bryan Donkin 205
  Election of New Members 206
  Appointments to Council 207
PROCEEDINGS, 4TH APRIL.—Business 209
  "Fencing of Steam- and Gas-Engines"; by H. D. Marshall (Plate 9) 211
  "Guarding of Textile Machinery"; by S. R. Platt (Plates 10-17) . 221
  "Protection of Lifts"; by H. C. Walker (Plates 18-21) . . . 231
  "Guarding Machine Tools"; by W. H. Johnson (Plates 22-26) . 241
PROCEEDINGS, 18TH APRIL—
  Election of New Members 295
  Transferences 298
  Anniversary Dinner 299
  "Standardization of Flanges"; by R. E. Atkinson (Plates 27-40) . 303
Conversazione 372
"Turning Mirrors for Search Lights"; by A. E. Pettit (Plate 41) . . 373
Memoirs 377
Index to Proceedings 1902, Parts 1-2 389
PLATES, 1-41.

PAST-PRESIDENTS.

George Stephenson, 1847–48. (*Deceased* 1848.)

Robert Stephenson, F.R.S., 1849–53. (*Deceased* 1859.)

Sir William Fairbairn, Bart., LL.D., F.R.S., 1854–55. (*Deceased* 1874.)

Sir Joseph Whitworth, Bart., D.C.L., LL.D., F.R.S., 1856–57, 1866. (*Deceased* 1887.)

John Penn, F.R.S., 1858–59, 1867–68. (*Deceased* 1878.)

James Kennedy, 1860. (*Deceased* 1886.)

The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S., 1861–62, 1869. (*Deceased* 1900.)

Robert Napier, 1863–65. (*Deceased* 1876.)

John Ramsbottom, 1870–71. (*Deceased* 1897.)

Sir William Siemens, D.C.L., LL.D., F.R.S., 1872–73. (*Deceased* 1883.)

Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S., 1874–75.

Thomas Hawksley, F.R.S., 1876–77. (*Deceased* 1893.)

John Robinson, 1878–79.

Edward A. Cowper, 1880–81. (*Deceased* 1893.)

Percy G. B. Westmacott, 1882–83.

Sir Lowthian Bell, Bart., LL.D., F.R.S., 1884.

Jeremiah Head, 1885–86. (*Deceased* 1899.)

Sir Edward H. Carbutt, Bart., 1887–88.

Charles Cochrane, 1889. (*Deceased* 1898.)

Joseph Tomlinson, 1890–91. (*Deceased* 1894.)

Sir William Anderson, K.C.B., D.C.L., F.R.S., 1892–93. (*Deceased* 1898.)

Professor Alexander B. W. Kennedy, LL.D., F.R.S., 1894–95.

E. Windsor Richards, 1896–97.

Samuel Waite Johnson, 1898.

Sir William H. White. K.C.B. LL.D. D.Sc., F.R.S., 1899–1900.

The Institution of Mechanical Engineers.

OFFICERS.

1902.

PRESIDENT.

William H. Maw,	London.

PAST-PRESIDENTS.

Sir Lowthian Bell, Bart., LL.D., F.R.S.,	Northallerton.
Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S.,	London.
Sir Edward H. Carbutt, Bart.,	London.
Samuel Waite Johnson,	Derby.
Professor Alexander B. W. Kennedy, LL.D., F.R.S.,	London.
E. Windsor Richards,	Caerleon.
John Robinson,	Leek.
Percy G. B. Westmacott,	Ascot.
Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.,	London.

VICE-PRESIDENTS.

John A. F. Aspinall,	Manchester.
Arthur Keen,	Birmingham.
Edward P. Martin,	Dowlais.
T. Hurry Riches,	Cardiff.
A. Tannett-Walker,	Leeds.
J. Hartley Wicksteed,	Leeds.

MEMBERS OF COUNCIL.

Sir Benjamin Baker, K.C.M.G., LL.D., D.Sc., F.R.S.,	London.
Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S.,	London.
Henry Chapman,	London.
Henry Davey,	London.
William Dean,	Swindon.
Edward B. Ellington,	London.
H. Graham Harris,	London.
Henry A. Ivatt,	Doncaster.
Henry Lea,	Birmingham.
Sir William T. Lewis, Bart.	Aberdare.
James Mansergh, F.R.S.,	London.
Henry D. Marshall,	Gainsborough.
The Right Hon. William J. Pirrie, LL.D.	Belfast.
Samuel R. Platt,	Oldham.
Sir Thomas Richardson,	Hartlepool.
John F. Robinson,	Glasgow.
Mark H. Robinson,	Rugby.
John W. Spencer,	Newcastle-on-Tyne.
John I. Thornycroft, LL.D., F.R.S.,	London.
John Tweedy,	Newcastle-on-Tyne.
Henry H. West,	Liverpool.

HON. TREASURER.

Harry Lee Millar.

AUDITOR.

Robert A. McLean, F.C.A.

SECRETARY.

Edgar Worthington,
The Institution of Mechanical Engineers,
Storey's Gate, St. James's Park, Westminster, S.W.
Telegraphic address:—*Mech, London.* Telephone:—*Westminster,* 264.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Memorandum of Association.

AUGUST 1878.

1st. The name of the Association is "THE INSTITUTION OF MECHANICAL ENGINEERS."

2nd. The Registered Office of the Association will be situate in England.

3rd. The objects for which the Association is established are:—

(A.) To promote the science and practice of Mechanical Engineering and all branches of mechanical construction, and to give an impulse to inventions likely to be useful to the Members of the Institution and to the community at large.

(B.) To enable Mechanical Engineers to meet and to correspond, and to facilitate the interchange of ideas respecting improvements in the various branches of mechanical science, and the publication and communication of information on such subjects.

(C.) To acquire and dispose of property for the purposes aforesaid.

(D.) To do all other things incidental or conducive to the attainment of the above objects or any of them.

4th. The income and property of the Association, from whatever source derived, shall be applied solely towards the promotion of the objects of the Association as set forth in this Memorandum of Association, and no portion thereof shall be paid or transferred directly or indirectly, by way of dividend, bonus, or otherwise howsoever, by way of profit to the persons who at any time are or have been Members of the Association, or to any of them, or to any person claiming through any of them: Provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Association, or to any Member of the Association, or other person, in return for any services rendered to the Association, or prevent the giving of privileges to the Members of the Association in attending the meetings of the Association, or prevent the borrowing of money (under such powers as the Association and the Council thereof may possess) from any Member of the Association, at a rate of interest not greater than five per cent. per annum.

5th. The fourth paragraph of this Memorandum is a condition on which a licence is granted by the Board of Trade to the Association in pursuance of Section 23 of the Companies Act 1867. For the purpose of preventing any evasion of the terms of the said fourth paragraph, the Board of Trade may from time to time, on the application of any Member of the Association, impose further conditions, which shall be duly observed by the Association.

6th. If the Association act in contravention of the fourth paragraph of this Memorandum, or of any such further conditions, the liability of every Member of the Council shall be unlimited; and the liability of every Member of the Association who has received any such dividend, bonus, or other profit as aforesaid, shall likewise be unlimited.

7th. Every Member of the Association undertakes to contribute to the Assets of the Association in the event of the same being wound up during the time that he is a Member, or within one year afterwards, for payment of the debts and liabilities of the Association contracted before the time at which he ceases to be a Member, and of the costs, charges, and expenses for winding up the same, and for the adjustment of the rights of the contributories amongst themselves, such amount as may be required not exceeding Five Shillings, or in case of his liability becoming unlimited such other amount as may be required in pursuance of the last preceding paragraph of this Memorandum.

8th. If upon the winding up or dissolution of the Association there remains, after the satisfaction of all its debts and liabilities, any property whatsoever, the same shall not be paid to or distributed among the Members of the Association, but shall be given or transferred to some other Institution or Institutions having objects similar to the objects of the Association, to be determined by the Members of the Association at or before the time of dissolution; or in default thereof, by such Judge of the High Court of Justice as may have or acquire jurisdiction in the matter.

Articles of Association.

FEBRUARY 1893.

(*Article* 23 *revised March* 1902.)

INTRODUCTION.

Whereas an Association called "The Institution of Mechanical Engineers" existed from 1847 to 1878 for objects similar to the objects expressed in the Memorandum of Association of the Association (hereinafter called "the Institution") to which these Articles apply;

And whereas the Institution was formed in 1878 for furthering and extending the objects of the former Institution, by a registered Association, under the Companies Acts 1862 and 1867;

And whereas terms used in these Articles are intended to have the same respective meanings as they have when used in those Acts, and words implying the singular number are intended to include the plural number, and *vice versâ*;

NOW THEREFORE IT IS HEREBY AGREED as follows:—

CONSTITUTION.

1. For the purpose of registration the number of members of the Institution is unlimited.

MEMBERS, ASSOCIATE MEMBERS, GRADUATES, ASSOCIATES, AND HONORARY LIFE MEMBERS.

2. The present Members of the Institution, and such other persons as shall be admitted in accordance with these Articles, and none others, shall be Members of the Institution, and be entered on the register as such.

3. Any person may become a Member of the Institution who shall be qualified and elected as hereinafter mentioned, and shall agree to become such Member, and shall pay the entrance fee and first subscription accordingly.

4. The qualification of Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

5. The election of Members shall be conducted as prescribed by the By-laws from time to time in force, as provided by the Articles.

6. In addition to the persons already admitted as Graduates, Associates, and Honorary Life Members respectively, the Institution may admit such persons as may be qualified and elected in that behalf as Associate Members, Graduates, Associates, and Honorary Life Members respectively of the Institution, and may confer upon them such privileges as shall be prescribed by the By-laws from time to time in force, as provided by the Articles: provided that no Associate Member, Graduate, Associate, or Honorary Life Member shall be deemed to be a Member within the meaning of the Articles.

7. The qualification and mode of election of Associate Members, Graduates, Associates, and Honorary Life Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

8. The rights and privileges of every Member, Associate Member, Graduate, Associate, or Honorary Life Member shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. The Entrance Fees and Subscriptions of Members, Associate Members, Graduates, and Associates shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

EXPULSION.

10. If any Member, Associate Member, Graduate, or Associate shall leave his subscription in arrear for two years, and shall fail to pay such arrears within three months after a written application has been sent to him by the Secretary, his name may be struck off the register by the Council at any time afterwards, and he shall thereupon cease to have any rights as a Member, Associate Member, Graduate, or Associate, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being so struck off: provided always that this regulation shall not be construed to compel the Council to remove any name, if they shall be satisfied the same ought to be retained.

11. The Council may refuse to continue to receive the subscriptions of any person who shall have wilfully acted in contravention of the regulations of the Institution, or who shall in the opinion of the Council have been guilty of such conduct as shall have rendered him unfit to continue to belong to the Institution; and may remove his name from the register, and he shall thereupon cease to be a Member, Associate Member, Graduate, or Associate (as the case may be) of the Institution.

GENERAL MEETINGS.

12. The General Meetings shall consist of the Ordinary Meetings, the Annual General Meeting, and of Special Meetings as hereinafter defined.

13. The Annual General Meeting shall take place in London in one of the first four months of every year. The Ordinary Meetings shall take place at such times and places as the Council shall determine.

14. A Special Meeting may be convened at any time by the Council, and shall be convened by them whenever a requisition signed by twenty Members or Associate Members of the Institution,

specifying the object of the Meeting, is left with the Secretary. If for fourteen days after the delivery of such requisition a Meeting be not convened in accordance therewith, the Requisitionists or any twenty Members or Associate Members of the Institution may convene a Special Meeting in accordance with the requisition. All Special Meetings shall be held in London.

15. Seven clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any Meeting, shall be given to every person on the register of the Institution, except as provided by Article 35, and no other special business shall be transacted at such Meeting; but the non-receipt of such notice shall not invalidate the proceedings of such Meeting. No notice of the business to be transacted (other than such ballot lists as may be requisite in case of elections) shall be required in the absence of special business.

16. Special business shall include all business for transaction at a Special Meeting, and all business for transaction at every other Meeting, with the exception of the reading and confirmation of the Minutes of the previous Meeting, the election of Members, Associate Members, Graduates, and Associates, and the reading and discussion of communications as prescribed by the By-laws, or by any regulations of the Council made in accordance with the By-laws.

PROCEEDINGS AT GENERAL MEETINGS.

17. Twenty Members or Associate Members shall constitute a quorum for the purpose of a Meeting other than a Special Meeting. Thirty Members or Associate Members shall constitute a quorum for the purpose of a Special Meeting.

18. If within thirty minutes after the time fixed for holding the Meeting a quorum is not present, the Meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at a Meeting (other than a Special Meeting) so dissolved, may forthwith be done on behalf of the Meeting by the Council.

19. The President shall be Chairman at every Meeting, and in his absence one of the Vice-Presidents; and in the absence of all Vice-Presidents a Member of Council shall take the chair; and if no Member of Council be present and willing to take the chair, the Meeting shall elect a Chairman.

20. The decision of a General Meeting shall be ascertained by show of hands, unless, after the show of hands, a poll is forthwith demanded; and by a poll, when a poll is thus demanded. The manner of taking a show of hands or a poll shall be in the discretion of the Chairman; and an entry in the Minutes, signed by the Chairman, shall be sufficient evidence of the decision of the General Meeting. Each Member and Associate Member shall have one vote and no more. In case of equality of votes the Chairman shall have a second or casting vote: provided that this Article shall not interfere with the provisions of the By-laws as to election by ballot.

21. The acceptance or rejection of votes by the Chairman shall be conclusive for the purpose of the decision of the matter in respect of which the votes are tendered: provided that the Chairman may review his decision at the same Meeting, if any error be then pointed out to him.

BY-LAWS.

22. The By-laws set forth in the schedule to these Articles, and such altered and additional By-laws as shall be substituted or added as hereinafter mentioned, shall regulate all matters by the Articles left to be prescribed by the By-laws, and all matters which consistently with the Articles shall be made the subject of By-laws. Alterations in, and additions to, the By-laws, may be made only by resolution of the Members and Associate Members at an Annual General Meeting, after notice of the proposed alteration or addition has been announced at the previous Ordinary Meeting, and not otherwise.

COUNCIL.

23. The Council of the Institution shall be chosen from the Members only, and shall consist of one President, six Vice-Presidents, twenty-one ordinary Members of Council, and of the Past-Presidents. The President, two Vice-Presidents, and seven Members of Council (other than Past-Presidents), shall retire at each Annual General Meeting, but shall be eligible for re-election. The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree otherwise among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot.

24. The election of a President, Vice-Presidents, and Members of Council, to supply the place of those retiring at the Annual General Meeting, shall be conducted in such manner as shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

25. The Council may supply any casual vacancy in the Council (including any casual vacancy in the office of President) which shall occur between one Annual General Meeting and another; and the President, Vice-Presidents, or Members of Council so appointed by the Council shall retire at the succeeding Annual General Meeting. Vacancies not filled up at any such Meeting shall be deemed to be casual vacancies within the meaning of this Article.

OFFICERS.

26. The Treasurer, Secretary, and other employés of the Institution shall be appointed and removed in the manner prescribed by the By-laws from time to time in force, as provided by the Articles. Subject to the express provisions of the By-laws, the officers and servants of the Institution shall be appointed and removed by the Council.

27. The powers and duties of the officers of the Institution shall, subject to any express provision in the By-laws, be determined by the Council.

POWERS AND PROCEDURE OF COUNCIL.

28. The Council may regulate their own procedure, and delegate any of their powers and discretions to any one or more of their body, and may determine their own quorum: if no other number is prescribed, three members of Council shall form a quorum.

29. The Council shall manage the property, proceedings, and affairs of the Institution, in accordance with the By-laws from time to time in force.

30. The Treasurer may, with the consent of the Council, invest in the name of the Institution any moneys not immediately required for the purposes of the Institution in or upon any of the following investments (that is to say):—

(A) The Public Funds, or Government Stocks of the United Kingdom, or of any Foreign or Colonial Government guaranteed by the Government of the United Kingdom.

(B) Real or Leasehold Securities, or in the purchase of real or leasehold properties in Great Britain or Ireland.

(C) Debentures, Debenture Stock, or Guaranteed or Preference Stock, of any Company incorporated by special Act of Parliament, the ordinary Shareholders whereof shall at the time of such investment be in actual receipt of half-yearly or yearly dividends.

(D) Stocks, Shares, Debentures, or Debenture Stock of any Railway, Canal, or other Company, the undertaking whereof is leased to any Railway Company at a fixed or fixed minimum rent.

(E) Stocks, Shares, or Debentures of any East Indian Railway or other Company, which shall receive a contribution from His Majesty's East Indian Government of a fixed annual percentage on their capital, or be guaranteed a fixed annual dividend by the same Government.

(F) The security of rates levied by any corporate body empowered to borrow money on the security of rates, where such borrowing has been duly authorised by Act of Parliament.

31. The Council may, with the authority of a resolution of the Members and Associate Members in General Meeting, borrow moneys for the purposes of the Institution on the security of the property of the Institution, or otherwise at their discretion.

32. No act done by the Council, whether *ultra vires* or not, which shall receive the express or implied sanction of the Members and Associate Members in General Meeting, shall be afterwards impeached by any member of the Institution on any ground whatsoever, but shall be deemed to be an act of the Institution.

NOTICES.

33. A notice may be served by the Council upon any Member, Associate Member, Graduate, Associate, or Honorary Life Member, either personally or by sending it through the post in a prepaid letter addressed to him at his registered place of abode.

34. Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post; and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the post office.

35. No Member, Associate Member, Graduate, Associate, or Honorary Life Member, not having a registered address within the United Kingdom, shall be entitled to any notice; and all proceedings may be had and taken without notice to such member, in the same manner as if he had had due notice.

By-laws.

(*Last Revision, February* 1894.)

MEMBERSHIP.

1. Candidates for admission as Members must be persons not under twenty-five years of age, who, having occupied during a sufficient period a responsible position in connection with the practice or science of Engineering, may be considered by the Council to be qualified for election.

2. Candidates for admission as Associate Members must be persons not under twenty-five years of age, who, being engaged in such work as is connected with the practice or science of Engineering, may be considered by the Council to be qualified for election, though not yet to occupy positions of sufficient responsibility, or otherwise not yet to be eligible, for admission as Members. They may afterwards be transferred at the discretion of the Council to the class of Members.

3. Candidates for admission as Graduates must be persons holding subordinate situations, and not under eighteen years of age. They must furnish evidence of training in the principles as well as in the practice of Engineering. Before attaining the age of twenty-six years, those elected after 1892 must apply for election as Members, Associate Members, or Associates, if they desire to remain connected with the Institution; they may not continue Graduates after attaining the age of twenty-six.

4. Candidates for admission as Associates must be persons not under twenty-five years of age, who from their scientific attainments or position in society may be considered eligible by the Council. They may afterwards be transferred at the discretion of the Council to the class of Associate Members or of Members.

5. The Council shall have the power to nominate as Honorary Life Members persons of eminent scientific acquirements, who in their opinion are eligible for that position.

6. The Members, Associate Members, Graduates, Associates, and Honorary Life Members shall have notice of and the privilege to attend all Meetings; but Members and Associate Members only shall be entitled to vote thereat.

7. The abbreviated distinctive Titles for indicating the connection with the Institution of Members, Associate Members, Graduates, Associates, or Honorary Life Members thereof, shall be the following:—for Members, M. I. Mech. E.; for Associate Members, A. M. I. Mech. E.; for Graduates, G. I. Mech. E.; for Associates, A. I. Mech. E.; for Honorary Life Members, Hon. M. I. Mech. E.

8. Subject to such regulations as the Council may from time to time prescribe, any Member, Associate Member, or Associate may upon application to the Secretary obtain a Certificate of his membership or other connection with the Institution. Every such certificate shall remain the property of, and shall on demand be returned to, the Institution.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. Each Member shall pay an Annual Subscription of £3, and on election an Entrance Fee of £2.

10. Each Associate Member shall pay an Annual Subscription of £2 10*s*., and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Members, he shall pay on transference 10*s*. additional subscription for the current year, and £1 additional entrance fee.

11. Each Graduate shall pay an Annual Subscription of £1 10*s*., but no Entrance Fee. Any Graduate elected prior to 1893, if transferred by the Council to the class of Associate Members, shall pay on transference £1 additional subscription for the current year, but no additional entrance fee; if transferred direct to the class of Members, he shall pay on transference £1 10*s*. additional subscription for the current year, and £1 additional entrance fee.

12. Each Associate shall pay an Annual Subscription of £2 10*s.*, and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Associate Members, he shall pay on transference no additional subscription or entrance fee. If transferred direct to the class of Members, he shall pay on transference 10*s.* additional subscription for the current year, and £1 additional entrance fee; except Associates elected prior to 1893, who shall pay no additional entrance fee on transference.

13. All subscriptions shall be payable in advance, and shall become due on the 1st day of January in each year; and the first subscription of Members, Associate Members, Graduates, and Associates, shall date from the 1st day of January in the year of their election.

14. In the case of Members, Associate Members, Graduates, or Associates, elected in the last three months of any year, the first subscription shall cover both the year of election and the succeeding year.

15. Any Member, Associate Member, or Associate, whose subscription is not in arrear, may at any time compound for his subscription for the current and all future years by the payment of Fifty Pounds, if paid in any one of the first five years of his membership. If paid subsequently, the sum of Fifty Pounds shall be reduced by One Pound per annum for every year of membership after five years. All compositions shall be deemed to be capital moneys of the Institution.

16. The Council may at their discretion reduce or remit the annual subscription, or the arrears of annual subscription, of any Member or Associate Member who shall have been a subscribing member of the Institution for twenty years, and shall have become unable to continue the annual subscription provided by these By-laws.

17. No Proceedings or Ballot Lists or Certificates shall be sent to Members, Associate Members, Graduates, or Associates, who are in

arrear with their subscriptions more than twelve months, and whose subscriptions have not been remitted by the Council as hereinbefore provided.

ELECTION OF MEMBERS, ASSOCIATE MEMBERS, GRADUATES, AND ASSOCIATES.

18. A recommendation for admission according to Form A or B in the Appendix shall be forwarded to the Secretary, and by him be laid before the next Meeting of the Council. The recommendation must be signed by not less than five Members or Associate Members if the application be for admission as a Member or Associate Member or Associate, and by three Members or Associate Members if it be for a Graduate.

19. All elections shall take place by ballot, four-fifths of the votes given being necessary for election.

20. All applications for admission shall be communicated by the Secretary to the Council for their approval previous to being inserted in the ballot list for election, and the approved ballot list shall be signed by the President and forwarded to the Members and Associate Members. The name of any Candidate approved by the Council for admission as an Associate Member or an Associate shall not be inserted in the ballot list until he has signed the Form C in the Appendix. The ballot list shall specify the name, occupation, and address of the Candidates, and also by whom proposed and seconded. The lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

21. The Elections shall take place at the General Meetings only.

22. When the proposed Candidate is elected, the Secretary shall give him notice thereof according to Form D; but his name shall not be added to the register of the Institution until he shall have paid his Entrance Fee and first Annual Subscription, and signed the Form E in the Appendix.

23. In case of non-election, no mention thereof shall be made in the Minutes, nor any notice given to the unsuccessful Candidate.

24. An Associate Member desirous of being transferred to the class of Members, or an Associate to the class of Associate Members or of Members, shall forward to the Secretary a recommendation according to Form F in the Appendix, signed by not less than five Members or Associate Members, which shall be laid before the next meeting of Council for their approval. On their approval being given, the Secretary shall notify the same to the Candidate according to Form G; but his name shall not be added to the list of Members or Associate Members until he shall have signed the Form H, and shall have paid the additional entrance fee (if any), and the additional subscription (if any) for the current year.

ELECTION OF PRESIDENT, VICE-PRESIDENTS, AND MEMBERS OF COUNCIL.

25. Candidates shall be put in nomination at the General Meeting preceding the Annual General Meeting, when the Council are to present a list of their retiring Members who offer themselves for re-election; any Member or Associate Member shall then be entitled to add to the list of Candidates. The ballot list of the proposed names shall be forwarded to the Members and Associate Members. The ballot lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

APPOINTMENT AND DUTIES OF OFFICERS.

26. The Treasurer shall be a Banker, and shall hold the uninvested funds of the Institution, except the moneys in the hands of the Secretary for current expenses. He shall be appointed by the Members and Associate Members at a General or Special Meeting, and shall hold office at the pleasure of the Council.

27. The Secretary of the Institution shall be appointed, as and when a vacancy occurs, by the Members and Associate Members at a General or Special Meeting, and shall be removable by the Council upon six months' notice from any day. The Secretary shall give the same notice. The Secretary shall devote the whole of his time to the work of the Institution, and shall not engage in any other business or profession.

28. It shall be the duty of the Secretary, under the direction of the Council, to conduct the correspondence of the Institution; to attend all meetings of the Institution, and of the Council, and of Committees; to take minutes of the proceedings of such meetings; to read the minutes of the preceding meetings, and all communications that he may be ordered to read; to superintend the publication of such papers as the Council may direct; to have the charge of the library; to direct the collection of the subscriptions, and the preparation of the account of expenditure of the funds; and to present all accounts to the Council for inspection and approval. He shall also engage (subject to the approval of the Council) and be responsible for all persons employed under him, and set them their portions of work and duties. He shall conduct the ordinary business of the Institution, in accordance with the Articles and By-laws and the directions of the President and Council; and shall refer to the President in any matters of difficulty or importance, requiring immediate decision.

MISCELLANEOUS.

29. All Papers shall be submitted to the Council for approval, and after their approval shall be read by the Secretary at the General Meetings, or by the Author with the consent of the Council; or, if so directed by the Council, shall be printed in the Proceedings without having been read at a General Meeting.

30. All books, drawings, communications, &c., shall be accessible to the members of the Institution at all reasonable times.

31. All communications to the Meetings shall be the property of the Institution, and be published only by the authority of the Council.

32. None of the property of the Institution—books, drawings, &c.—shall be taken out of the premises of the Institution without the consent of the Council.

33. All donations to the Institution shall be enumerated in the Annual Report of the Council presented to the Annual General Meeting.

34. The General Meetings shall be conducted as far as practicable in the following order:—

1st. The Chair to be taken at such hour as the Council may direct from time to time.

2nd. The Minutes of the previous Meeting to be read by the Secretary, and, after being approved as correct, to be signed by the Chairman.

3rd. The Ballot Lists, previously opened by the Council, to be presented to the Meeting, and the new Members, Associate Members, Graduates, and Associates elected to be announced.

4th. Papers approved by the Council to be read by the Secretary, or by the Author with the consent of the Council.

35. Each Member or Associate Member shall have the privilege of introducing one friend to any of the Meetings; but, during such portion of any meeting as may be devoted to any business connected with the management of the Institution, visitors shall be requested by the Chairman to withdraw, if any Member or Associate Member asks that this shall be done.

36. Every Member, Associate Member, Graduate, Associate, or Visitor, shall write his name and residence in a book to be kept for the purpose, on entering each Meeting.

37. The President shall ex officio be member of all Committees of Council.

38. Seven clear days' notice at least shall be given of every meeting of the Council. Such notice shall specify generally the business to be transacted by the meeting. No business involving the expenditure of the funds of the Institution (except by way of payment of current salaries and accounts) shall be transacted at any Council meeting unless specified in the notice convening the meeting.

39. The Council shall present the yearly accounts to the Annual General Meeting, after being audited by a professional accountant, who shall be appointed annually by the Members and Associate Members at a General or a Special Meeting, at a remuneration to be then fixed by the Members and Associate Members.

40. Any member wishing to have a copy of the Papers sent to him for consideration beforehand can do so by sending in his name once in each year to the Secretary; and a copy of all Papers shall then be forwarded to him as early as possible prior to the date of the Meeting at which they are intended to be read.

41. At any Meeting of the Institution any member shall be at liberty to re-open the discussion upon any Paper which has been read or discussed at the preceding Meeting; provided that he signifies his intention to the Secretary at least one month previously to the Meeting, and that the Council decide to include it in the notice of the Meeting as part of the business to be transacted.

APPENDIX.

FORM A.

Mr. being years of age, and desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the three other signers from trustworthy information, propose and recommend him as a proper person to belong to the Institution.

Witness our hands, this day of

Members or Associate Members.

FORM B.

Mr. born on being desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the other signer or signers from trustworthy information, propose and recommend him as a proper person to become a Graduate thereof.

Witness our hands, this day of

Members or Associate Members.

FORM C.

If elected an of The Institution of Mechanical Engineers, I, the undersigned, do hereby engage to ratify my election by signing the form of agreement (E) and paying the Entrance Fee and Annual Subscription in conformity with the By-laws.

Witness my hand, this day of

FORM D.

Sir,—I have to inform you that on the you were elected a of The Institution of Mechanical Engineers. For the ratification of your election in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your Entrance Fee and first Annual Subscription be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the election will become void.

I am, Sir, Your obedient servant,

Secretary.

FORM E.

I, the undersigned, being elected a of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they are now formed or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of

FORM F.

Mr. being years of age, and desirous of being transferred into the class of of The Institution of Mechanical Engineers, we, the undersigned, from our personal knowledge recommend him as a proper person to be so transferred by the Council.

Witness our hands, this day of

Members or Associate Members.

FORM G.

Sir,—I have to inform you that the Council have approved of your being transferred to the class of of The Institution of Mechanical Engineers. For the ratification of your transference in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your additional Entrance Fee and additional Annual Subscription for the current year be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the transference will become void.

I am, Sir, Your obedient servant,

Secretary.

FORM H.

I, the undersigned, having been transferred to the class of of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they now exist, or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of

The Institution of Mechanical Engineers.

PROCEEDINGS.

JANUARY 1902.

An ORDINARY GENERAL MEETING was held at the Institution on Friday, 17th January 1902, at Eight o'clock p.m.; WILLIAM H. MAW, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The PRESIDENT informed the Members that the Council had had under their consideration the desirability of enlarging the number of ordinary Members of Council. Apart from the Past-Presidents, the Council at present consisted of the President, six Vice-Presidents, and fifteen ordinary Members of Council. The Council proposed to bring forward at the next Annual General Meeting, on 21st February, a motion to increase the number of ordinary Members of Council from fifteen to twenty-one. It was not necessary on the present occasion to enter into the reasons for the proposed change, as that would be done when the motion was brought forward; but he might mention that one of the chief objects the Council had in view was to enable provincial centres to be more thoroughly represented on the Council than they were now. Before the next Meeting, Members would receive a formal statement of the motion which was to be brought forward, so that it could be discussed and thoroughly considered.

The PRESIDENT announced that, in accordance with the Rules of the Institution, the President, two Vice-Presidents, and five Members of Council, would retire at the ensuing Annual General Meeting; and the list of those retiring was as follows:—

PRESIDENT.

WILLIAM H. MAW,	London.

VICE-PRESIDENTS.

BRYAN DONKIN,	London.
EDWARD P. MARTIN,	Dowlais.

MEMBERS OF COUNCIL.

HENRY DAVEY,	London.
EDWARD B. ELLINGTON,	London.
Sir WILLIAM T. LEWIS, Bart.,	Aberdare.
The Right Hon. W. J. PIRRIE, LL.D.,	Belfast.
Sir THOMAS RICHARDSON,	Hartlepool.

All of the above had offered themselves for re-election.

The following Nominations had also been made by the Council for the election at the Annual General Meeting:—

MEMBERS OF COUNCIL.

Election as Member.		
1860.	HENRY LEA,	Birmingham.
1875.	JAMES MANSERGH, F.R.S.,	London.
1894.	MARK H. ROBINSON,	Rugby.

All of the above had consented to the Nomination.

The PRESIDENT reminded the Meeting that, according to the Rules of the Institution, any Member or Associate Member was now entitled to add to the list of candidates.

No other names being added, the President announced that the foregoing names would accordingly constitute the nomination list for the Election of Officers at the Annual General Meeting.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following one hundred and nineteen candidates were found to be duly elected :—

MEMBERS.

Andrews, Thomas,	Belfast.
Bennett, Arthur Edward,	Coventry.
Carpenter, Charles Claude,	London.
Clacher, Daniel,	London.
Conner, James,	Kilmarnock.
Cormack, John Dewar,	London.
Finlayson, Richard Wilson,	Sydney.
Foggo, Watson,	London.
Gebbie, John,	Singapore.
Greaves, William,	Leeds.
Haarer, Ernest Du Chaillu,	Liverpool.
Harris, William,	London.
Haswell, Frederick John,	Liverpool.
Hayward, Thomas William Alfred,	Sudbury, Suffolk.
Hignett, Arthur Holland,	Crewe.
Lukis, Wilfrid Ravenshaw Fellowes,	Colombo.
Mortimore, William,	Manchester.
Muckley, William Henry,	Liverpool.
Prescott, Walter Henry,	London.
Ross, John,	Wigan.
Sainty, Christopher,	Eton, Windsor.
Sharman, Philip Alan,	Hitchin.
Walker, Percy,	Belvedere, Kent.
Wallace, John Crawford,	London.
Ward, Sydney Asline,	Sheffield.
Whittaker, Frederick William,	Bradford.
Wood, Hervey Alan,	Jamalpore, India.

ASSOCIATE MEMBERS.

Abbott, Robert Hill,	Manchester.
Bell, Frank,	Derby.

Blagden, Henry Robert Cecil,	Alexandria.
Bott, Walter Stanley,	Newark.
Bow, John,	Buenos Aires.
Busfeild, William,	Leeds.
Collyer, Percy Nicholson,	Jarrow-on-Tyne.
Cotsworth, Haldane Gwilt,	London.
Coulson, Horace Ernest,	London.
Cramb, Alexander Charles,	London.
Crawford, Gerald Walker,	Edinburgh.
Dixon, John,	Glasgow.
Dryden, William,	Preston.
Eaton, George Henry,	London.
Embleton, Charles Arnold,	London.
Epps, Laurence George John,	London.
Foster, Sydney,	Fleetwood, Lancs.
George, John William,	London.
Golledge, William Thomas,	London.
Goudie, William John,	Glasgow.
Hale, Harold,	Winchester.
Haler, Percy James,	Burslem, Staff.
Hardcastle, Edward,	Newlay, near Leeds.
Hardy, James Henry,	Halifax.
Harper, Neville Charles Thomason,	Durban, Natal.
Hathorn, James Charles Murray,	Folkestone.
Hawksley, Charles William,	Sheffield.
Henderson, Donald Douglas,	London.
Hincks, John Murray,	Mysore, India.
Holden, Eustace Charles,	Bolton.
Holland, Bernard Augustus,	Leeds.
Hunt, Frank,	Earl's Colne, Essex.
Jarvis, Richard,	Moscow.
Johnson, Frederick Augustus,	Leeds.
Johnston, Leonard,	Manchester.
Jukes, Joseph William,	Leeds.
Keable, Alfred Henry,	London.
King, Henry James Hubert,	Nailsworth, Glos.

LAMPARD, PERCY,	Simla, India.
LEWENZ, HENRY IVAN,	London.
LUPTON, NORMAN DARNTON,	Leeds.
MACNAB, THOMAS POLLOCK,	Manchester.
MARSDEN, ALFRED,	Windsor.
MASCALL, ARTHUR EDWARD,	Glasgow.
McGHEE, ALEXANDER,	London.
MENSFORTH, HOLBERRY,	Bradford.
MOORE, THOMAS READE,	London.
NEWBIGGING, JOHN,	Dublin.
NEWMAN, WILLIAM HENRY,	Totteridge Park, Herts.
PETTIT, ARTHUR EDWARD,	Germiston, Transvaal.
PHILPOT, HAROLD PERCY,	London.
REID, JOHN WILSON,	London.
SANDFORD, JOHN,	Twickenham.
SCHONTHEIL, THEODORE,	Cardiff.
SCOTT, HENRY,	Christchurch, N.Z.
SMAIL, CHARLES GEORGE,	Sunbury-on-Thames.
SMITH, HUGH LESLIE,	Woolwich.
STARLEY, RICHARD,	Coventry.
STENNING, HUGH WALTER,	Shendy, Soudan.
STIRLING, JOHN MAXWELL,	Madras.
SUMNER, LEONARD,	Manchester.
TOWNEND, SIDNEY,	Shortlands, Kent.
TRAVIS, EDWIN,	Manchester.
TURPIN, WILLIAM ALFRED,	Glasgow.
WADE, FRANCIS RICHARD,	Coventry.
WEST, WILLIAM POWNOLL,	Alcaracejos, Spain.
WHICHELLO, RICHARD EDWARD,	Calcutta.
WHITELOCK, WILLIAM HENRY,	Plymouth.
WINGATE-SAUL, ARTHUR WINGATE,	Rugby.
WINSTANLEY-WALLIS, TACY MILLETT,	London.

GRADUATES.

BEXON, RALPH AMOS,	Nottingham.
CHABOT, VINCENT HOWARD,	London.

Cooper, Jasper Edwin,	Hull.
Dodridge, Albert Edwin,	London.
George, Albert James,	London.
Hatfield, Kenneth George Stacy,	Doncaster.
Hatton, Robert Andrew,	London.
Hayward, George,	London.
Heald, Harry,	Accrington.
Heard, Frederick George,	London.
Inchley, William,	Nottingham.
Kirlew, Richard Leopold, Jun.,	London.
Mason, Charles Lyall,	Crewe.
Morgan, Henry Frederick Stanley,	Swindon.
Morris, Cyril Clarke Boville,	London.
Munyard, Alfred Walford,	London.
Steed, Alfred William,	London.
Talbot, Ernest,	Sheffield.
Whittingham, Percival,	Manchester.
Wolstenholme, Walter,	Bolton.
Wood, Charles Cuthbert,	Bedford.
York, Richard Lister,	Leeds.

The following seven Transferences had been made by the Council since the last announcement:—

Associate Members to Members.

Barber, Thomas Walter,	London.
Douglas, William James,	London.
Furness, Charles,	Devonport.
Haines, Charles James,	Otterbourne, Hants.
Hitchins, Charles Faunce,	London.
Honiball, Charles Roland,	Liverpool.
Ticehurst, Hugh Gorham,	Erith.

The following Paper was read and partly discussed:—

"Modern Machine Methods"; by Mr. H. F. L. Orcutt, *Member*, of London.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 222 Members and 129 Visitors.

PROCEEDINGS.

31st JANUARY 1902.

An EXTRA MEETING was held at the Institution on Friday, 31st January 1902, at Eight o'clock p.m.; WILLIAM H. MAW, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The Discussion was resumed on Mr. Orcutt's Paper on "Modern Machine Methods," and was again adjourned to the Annual General Meeting.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 101 Members and 81 Visitors.

MODERN MACHINE METHODS.

By MR. H. F. L. ORCUTT, *Member*, OF LONDON.

There is a rapidly increasing tendency to minimise hand labour, and to reduce manufacturing to purely machine operations by the aid of accurate tools and fixtures combined with properly adapted machines. Admitting this, it follows that the lines on which manufacturers will work in the future will mainly be in the direction of perfecting methods of machining.

It is with respect to machine operations, where accuracy combined with cheapness of product is secured, that this Paper deals, contrasting modern developments with those methods where accuracy is secured only by laboriously expensive hand work, or where machine work is performed on tools of comparatively simple design, unaided by highly developed tools, fixtures, and gauges. It is not, however, assumed that automatic machine operations are invariably more economical than hand work, as doubtless many a sadder and wiser manufacturer who has invested in complicated expensive machines can testify. It is, however, beyond dispute that the producing power of the individual, aided by the labour-saving automatic machine, is practically unlimited, whilst we have long since reached the limit of production of the skilled worker, making use of only simple machines and hand tools. A high degree of accuracy is possible by either the old or the new method; but accuracy combined with cheapness is only possible under new conditions, whilst interchangeability is commercially impossible, except in those establishments fitted with the best machines, tools, and gauges.

Strictly speaking, there are few, if any, mechanical operations that may be called new since the time when the planer and milling machines superseded the chisel, and the power lathe and the drilling machine replaced the bow stick. Turning, milling, planing, grinding, and boring are as " old as the hills." It is the latter-day developments of these operations in which the progressive manufacturer is interested, developments which have practically taken place within the last twenty years, some of them within the last five years. It is proposed to touch briefly upon the different methods in respect to the latest practice only, and to deal finally with the workshop reforms which in some cases follow, and in others must precede, the introduction of new methods, before such methods can be successfully adopted.

The range of subjects is so large that in most cases ambiguity has been risked for the sake of brevity. Descriptions of methods of working have not been possible, and an attempt only has been made to mention the most important points to which modern manufacturers must give attention. Technical details as to constructive features of machines have been avoided. The chief aim has been to make the Paper suggestive to those who are considering economical methods of manufacture.

Gauges.—It is altogether too commonly supposed that the extensive use of accurate gauges is only economical where either highly accurate work is called for or parts are to be made in large quantities. Neither supposition is correct. In nine cases out of ten where even only one piece is concerned, that piece can be produced more cheaply and better with the aid of proper gauges than by the old-fashioned method of " fitting," or by measuring with micrometers or calipers. There will be the additional advantage of pieces being practically interchangeable. Again, where comparatively coarse work, as for instance in some parts of a loom, is permissible, the use of suitable gauges is desirable for the reason that, no matter how loose the fits may be, it is necessary, to save work in erecting, to secure interchangeability and to keep sizes within certain limits. All this can be accomplished by means of the "limit" gauge, whether used for large or small dimensions, for inside or outside work, or for running or driving fits. Although the "limit" gauge in certain forms has been in use for years, particularly amongst gun and small-arms makers, it is surprising how little its advantages and use are known and understood by manufacturers for every-day work or all sorts. It is impossible to enumerate or describe the various forms of limit gauges which can be adopted in nearly all engineering works, but manufacturers will find the subject well worth investigation.

When the advantages of working with limit gauges are better understood, the system is sure to be extensively adopted for general engineering purposes, and limit gauges will supersede, except in a few cases, the ordinary standard plug and ring gauges. Even where the best gauges, of the ordinary sort, are used, work is in reality finished within certain "limits." When only standard gauges are used, however, these limits are never known; dimensions are made in accordance with the skill, judgment, or experience of the workman. With the limit-gauge system, it is only necessary to determine what the allowable limits are to be and to then make use of a maximum and minimum gauge, by which sizes are kept within the prescribed limits. For inside cylindrical work the form of gauge used is shown in Fig. 1 (page 12), for outside work those shown in Figs. 2 and 3. With these gauges, comparatively unskilled labour will (aided by the proper outfit) quickly learn to produce work accurately within limits of 0·0006 inch when using the external limit gauge and within limits of 0·0016 inch when using the internal limit gauge. These limits are none too close for a large percentage of ordinary engineering work and close enough for interchangeability, even in fine machine work. The adoption of limit gauges is in itself desirable, but of course the most economical results cannot be secured without also giving consideration to the outfit of machines and tools. It does not follow that grinding is necessary either for inside or outside work. The above limits can be kept to either in lathe or screw-machine work, and holes can be finished in steel, brass, or cast-iron with reamers.

It is an erroneous idea to suppose that because comparatively rough work is in question, comparatively rough gauges are "good enough." This may be true, as in the case of working gauges for unfinished material, but it will be rarely found profitable to follow this principle where machined surfaces are to be dealt with. Carefully finished hardened gauges, accurate to within 0·0001 inch, are none too good where working surfaces are in question. A finer degree of accuracy than this is not demanded, except in comparatively small work, as for instance, in tools connected with the manufacture of watches. It is proved that 0·0001 inch is a limit to which hardened gauges can be made without too great an expense. It is desirable not to go below this degree of accuracy for working gauges (never in the case of standards), as errors multiply rapidly, and four or five times this limit means that in many cases work must be rejected.

Limit Gauges. Examples from Table 1.

FIG. 1. *Internal.*

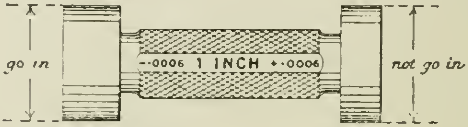


FIG. 2. *External Running Fit.*

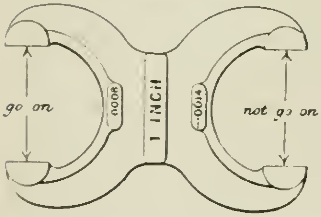
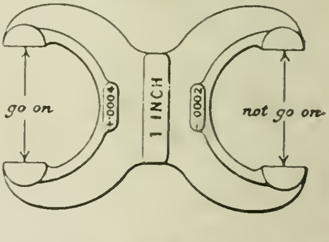


FIG. 3. *External Keying Fit.*



The following Table 1 of limits given is one which is adapted to a large range of work :—

TABLE 1.—*Internal and External Limit Gauges.*

Limits of tolerance expressed decimally in inches.

INTERNAL LIMIT GAUGES.

(*See Fig.* 1.)

Diameter of Holes. (Nominal.)	Go in.	Not go in.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{13}{32}$ inch.	− 0·0004	+ 0·0004	0·0008
$\frac{7}{16}$ inch to $\frac{11}{16}$ inch.	− 0·0006	+ 0·0004	0·0010
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	− 0·0006	+ 0·0006	0·0012
$1\frac{1}{4}$ inch to $1\frac{7}{8}$ inch.	− 0·0008	+ 0·0006	0·0014
$1\frac{15}{16}$ inch to $2\frac{15}{16}$ inches.	− 0·0008	+ 0·0008	0·0016
3 inches to $4\frac{9}{16}$ inches.	− 0·0010	+ 0·0008	0·0018

EXTERNAL LIMIT GAUGES, for running fits.

(*See Fig.* 2.)

Diameter of Shafts. (Nominal.)	Go on.	Not go on.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{13}{32}$ inch.	− 0·0004	− 0·0010	0·0006
$\frac{7}{16}$ inch to $\frac{11}{16}$ inch.	− 0·0006	− 0·0012	0·0006
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	− 0·0008	− 0·0014	0·0006
$1\frac{1}{4}$ inch to $1\frac{7}{8}$ inch.	− 0·0010	− 0·0018	0·0008
$1\frac{15}{16}$ inch to $2\frac{15}{16}$ inches.	− 0·0012	− 0·0020	0·0008
3 inches to $4\frac{9}{16}$ inches.	− 0·0014	− 0·0024	0·0010

EXTERNAL LIMIT GAUGES, for keying fits.

(*See Fig.* 3, *page* 12.)

Diameter of Shafts. (Nominal.)	Go on.	Not go on.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{13}{32}$ inch.	+ 0·0004	– 0·0002	0·0006
$\frac{7}{16}$ inch to $\frac{11}{16}$ inch.	+ 0·0004	– 0·0002	0·0006
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	+ 0·0004	– 0·0002	0·0006
$1\frac{1}{4}$ inch to $1\frac{7}{8}$ inch.	+ 0·0004	– 0·0004	0·0008
$1\frac{15}{16}$ inch to $2\frac{15}{16}$ inches.	+ 0·0004	– 0·0004	0·0008
3 inches to $4\frac{9}{16}$ inches.	+ 0·0004	– 0·0004	0·0008

Light Milling.—The field of operation for the milling machine has materially widened within a comparatively short time. Improvements in design and increased skill in the manipulation and care of tools are the two factors mainly responsible for its success. It has largely displaced the planer and shaper; it produces highly finished and accurate surfaces, and makes substantial savings in hand labour; it is designed with a view to adaptability in making short runs. In many cases it is found profitable to set up a machine for a run on ten or a dozen parts. Stability and quickness of manipulation are the chief characteristics of the modern milling machine as compared with those of older design. Wherever it can be adopted it usually scores over the planer or shaper as a labour saver, for the reason that in nearly all cases it can be served by unskilled attendants who can keep from two to four, and even six, machines in operation; whilst with the planer or shaper it is not very often the case that one operator can advantageously attend more than two machines.

One of the simplest and most effective methods is neglected to an astonishing degree, even by those who have large milling equipments; that is, taking a roughing and then a finishing cut, not hurrying the machine too much on the finishing cut. The milling machine is too often regarded as a means for merely removing metal instead of as an instrument for producing accurately finished surfaces where little or no hand work is necessary. In many cases five minutes more on the machine would make a saving of ten minutes fitters' work, files would be saved and greater uniformity secured. It should not be forgotten that the wrongly designed, badly made, rarely sharpened milling cutter largely assists in keeping the milling machine in disrepute, when otherwise it might rise to the rank of a valued ally.

The adoption and profitable use of the milling machine is often impossible on account of the lack of exact knowledge as to the composition of cast-iron, and for want of proper treatment of castings for the removal of sand and scale. A large percentage of castings which are used could be soft if cupola mixtures were properly regulated. This would allow fast speeds and feeds for the milling cutters, without breakages or too much wear, instead of the comparatively slow planer cuts where castings are hard. There is little comprehension of how much the want of laboratory work stands in the way of the adoption of the milling machine. The pickling of castings alone makes it possible to increase the product of milling and planing machines, saves cutting tools, and consequently makes good work easier. Milling in many cases easily reduces costs 50 per cent. when compared with planing.

There are three essentials to economical results in milling :—

(1) Up-to-date machines.
(2) A not too niggardly supply of good milling cutters and tools.
(3) Good tool-makers who know how to keep machines and tools in the best condition.

The following may be mentioned as a few of the most interesting milling operations which are not as widely adopted as they will be when their advantages are better understood.

The Vertical Milling Machine or, what amounts to the same, the Horizontal Machine, performing operations with the end mill, produces in many cases very satisfactory results both in speed and accuracy. There is a good variety of excellent machines, both of the vertical and horizontal type, now on the market for this class of work.

A most valuable machine, comparatively little used, is a combined vertical and horizontal machine with long table. For taking roughing cuts with fast feeds, inserted tooth cutters with Mushet blades give good results.

The Circular mill, either on simple or complicated forms, effects great savings, and one attendant can keep six machines in operation. It can also be run in connection with other milling machines, reducing costs in many cases 50 per cent. and 75 per cent., and competing with the best turning machines in accuracy as well as in costs of operation, Plate 1. On castings with a chemical composition suitable for change gears, pulleys, hand wheels, and similar parts to those shown in Fig. 6, circular milling is accomplished with the cutter running at a surface speed of over 50 feet per minute and work feeding 4 inches per minute on the periphery.

Heavy Milling.—The anticipated annihilation of the Planing Machine is not yet a reality, as some milling machine enthusiasts have from time to time predicted, and for heavy work the honours are now fairly well divided between the miller and the planer. Where rough but comparatively true surfaces only are required, what is known as the rotary planer turns out remarkably cheap work. It has the advantages of requiring little attendance and of turning out work two or three times faster than the planer; the cutters used are mostly of the inserted teeth pattern with self-hardening steel. Another profitable use to which the heavy mill has been put is in "roughing out" work, particularly on castings which are to be accurately finished afterwards on the planing machine. The author has known cases where this operation effected a saving of 75 per cent. in time. The rate of feed which can be commonly made use of varies from 2 inches to 6 inches per minute. One particular case which he has in mind as an illustration of profitable milling is that of roughing out lathe-beds. The cutter is perhaps 23 inches wide, and removes from ¼ inch to ½ inch of metal with a feed of about 3½ inches per minute, the peripheral speed of cutter being about 45 inches per minute. Lathe-beds are roughed out in this manner at about a fourth or a third of the labour cost when done on the planer, Fig. 7, Plate 2. In this case the beds are afterwards allowed to stand about two weeks to "season," then a light finishing-cut is taken by the planer, and then they are ready for being scraped. The regularity of cut varies of course with the material, whether it is hard or soft, accurate to size or not, or whether sand has been thoroughly removed from castings. Pickling and compositions of castings of course largely affect the possibilities of heavy as well as of light milling. Splendid results of heavy milling are attained by taking roughing and finishing cuts; surfaces of complicated shape up to 20 inches to 24 inches in width are finished outright on the heavy mill, and are then ready for being scraped. Good gains are made over the planer, in some cases even when on short runs. Cutters are sometimes expensive, even costing £25 and £30, often more, but they are good investments as labour-saving tools. The variety of heavy milling machines now on the market is large, so that good selections can be made for all classes of work.

The adoption of the milling machine is not as extensive as it should be, for the reason that often an apparently formidable investment in cutters is necessary. The milling cutter, however, should be looked upon as any other labour-saving tool. It is not so much a question of how much does it cost, as how much does it save, or how much does the article cost which it turns out.

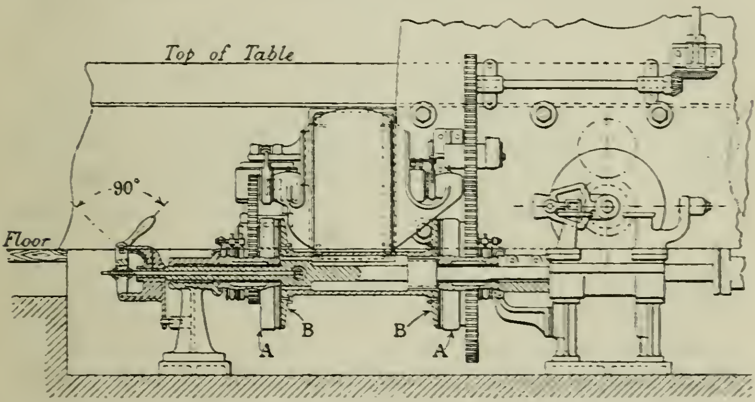
Planing.—The Planer is a much neglected, long-suffering machine, too often found in such dismal, unfavourable quarters that any attempts to improve either the accuracy or quantity of its product would be of little avail. Daylight and good foundations are commonly wanting in the planer department. Most of the improvements connected with the latter-day practice in planer work are seemingly of little importance, but when added together give a substantial total. They can be briefly enumerated.

A quick return stroke is a feature of all up-to-date planers. This is now rarely less than three to one on machines up to 36 inches capacity, and on smaller sizes four to one is common. Where castings are of good quality and the machine is well designed, cutting speeds are maintained of from 25 to 30 feet per minute and even up to 40 feet. Where castings are hard, either through design or ignorance, cutting speeds are necessarily lower. There is an immense amount of planing being done at cutting speeds of from 12 to 18 feet per minute which could be done at the rate of from 20 to 25 feet. All planers of 24 inches capacity and upwards should have two heads and larger sizes, three and four. One of the most highly productive planers the author has seen is a 24-inch machine with four heads and a 24-feet bed; it runs a close race with fast milling machines. It is claimed by a well-known machine-tool manufacturer that good savings are effected by the use of variable speed countershafts with which all their planers are fitted, as they can vary the speed of planers at will in accordance with the quality of material, length of stroke, and depth of cut. The author has seen in but one shop a simple device which saved considerable time; it was a brake in the form of a wooden shoe, which pressed on the fast running countershaft pulleys when the belt was thrown off. All the best types of planers are quickly manipulated by an easy working lever by which the machine can be started, stopped, or reversed. Few planer hands realize the time saved by good holding-devices, clamps, dogs, wedges, and quickly adjustable blocking pieces. Where any quantity of parts are to be planed, properly arranged jigs are of as much importance as for the milling machine. Block templates which clamp to planer bed are extremely useful devices for complicated shapes. An illustration of this gauge as used for lathe-beds is shown in Fig. 8, Plate 2.

Electric chucks for thin parts are the latest and most useful innovations. An exceedingly simple and useful little tool is the block gauge. It is cheap, lessens the chances of mistakes being made in measuring, and saves time in setting tools. The practice of periodically levelling the planer beds is astonishingly neglected, yet it is absolutely essential for good work.

The magnetic clutch driving mechanism, Fig. 9, promises to be a most important improvement in planer construction. This consists essentially of two magnetic clutch discs A, which are revolved in opposite directions and at speeds corresponding with the forward and return stroke of the planer table. The current is automatically switched by dogs on the table to either one clutch disc or the other. They alternately attract and grip discs B, shown in section, which are connected by a sleeve, and which slides endwise on the driving shaft of the planer to which they are keyed. Reference to drawing will show that these discs are so made that fly-wheel effect is reduced to a minimum. This arrangement makes it possible to reverse a planer table with a motive power very little in excess of that required to drive it. With the ordinary belt-drive the amount of power consumed at the moment of reversal is from 75 to 100 per cent. in excess of that necessary to move the table when under cut, whereas with the Riddell electric clutch drive on a 72-inch planer the increase in power is only about 15 per cent. The mechanism is practically noiseless and reverses more accurately to a line than with a belt drive.

FIG. 9. *Magnetic Clutch applied to driving an 84-inch Planer.* (Riddell.)



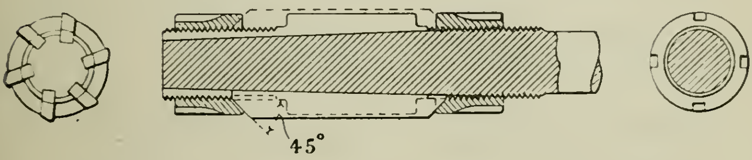
Grinding.—Grinding is probably the most ancient of all mechanical operations. As an operation by which accurate surfaces are cheaply produced, it is, however, a development of the last few years. The Plain and Universal Grinding Machine, in its latest form, is now a manufacturing machine as much as the lathe or milling machine; its use is no longer restricted to the "tool room" or for finishing hardened parts. It is conceded by those who use the grinder extensively and are expert in manipulating it, that it is the cheapest as well as the best machine for producing, mechanically, correct cylindrical surfaces where good work and interchangeability are desirable. This is true respecting soft as well as hard steel, cast-iron or bronze. The turner and the file cannot compete with the grinding machine and the limit gauge. The author believes it is safe to state that (excepting in heavy work) the grinding machine and the turret lathe will in the near future absorb 50 per cent. of the lathe work now performed by skilled turners. Parts can be roughed out on lathes by unskilled attendants, each running from two to three lathes, allowing from 0·006 to 0·008 inch on parts up to 4 inches diameter for finishing, and then accurately finished almost to the nicety of a gauge on grinding machines, one operator keeping two of these machines at work. For good cylindrical grinding, machines of extreme stability are necessary to resist vibration; they must be of the very best workmanship and capable of handling a large stream of water, by which the work is kept at an even temperature. Accurate limit-gauges are of great assistance as measuring instruments in the grinding department, for they can be more readily used in many instances than micrometers or vernier calipers.

Surface grinders, where accuracy is necessary, are not much used except where comparatively small areas are in question. Where accuracy is not of much importance, they will be found effective for a great deal of work, and more economical than hand polishing. One man can keep from four to five machines in operation. They are best when arranged with exhaust pipes for removing dust, as the present machines are not constructed to be used with a stream of water. As for planers, electric chucks are again "the latest" and most useful accessories to surface grinders.

Where accuracy is required on flat surfaces, except those of small dimensions, nothing in the way of a machine operation has been devised to take the place of hand scraping, or, where hardened surfaces are in question, hand lapping.

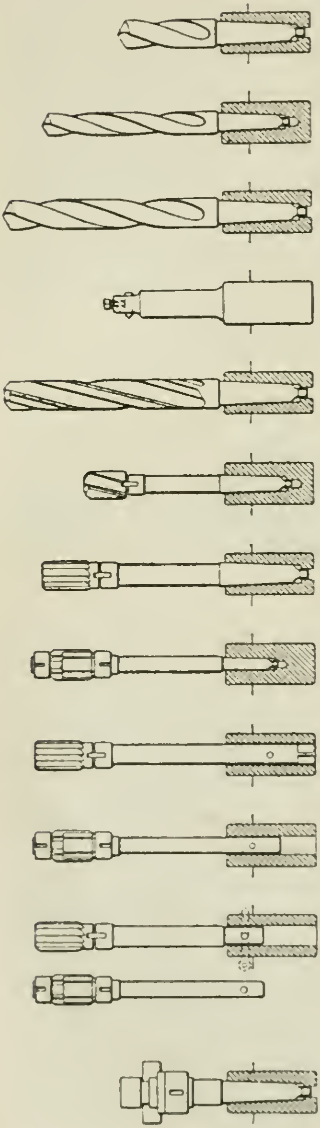
The most striking example of advanced practice in cylindrical grinding is that of work recently done on a machine capable of finishing parts up to 18 inches in diameter and up to 8 feet long, carrying a grinding wheel 24 inches in diameter with a 2-inch face. It is recorded that a 4-inch shaft 3 feet long can be finished on this machine in six minutes. The shaft is first rough turned with a 12-per-inch feed, and left 0·01 inch above size at the bottom of the tool marks. Parts up to 7 inches diameter are rapidly finished, the limit of variation being 0·001 inch. Knowing that results like the above have been accomplished, few manufacturers can neglect to consider seriously grinding as an important method by which costs may be reduced and quality of work improved.

FIG. 10.—*Adjustable Reamer.*



Chucking.—Chucking is an American term used to designate that class of work in which the part is held in a face plate chuck in either a vertical or horizontal turret machine, and is operated upon by a series of tools which finish a cylindrical hole. Comparatively true cylindrical surface, cheapness of operation, and interchangeability are virtues sufficient to recommend a proper system of chucking to enterprising manufacturers. Its adoption in accordance with the best practice need not be restricted to those who make only in large quantities or turn out very close work. Whether there is one piece or 500 to be "chucked," whether the "fit" has 1–64th inch or 2–1000th inch play, the system is profitable. In the same manner that milling is specialised to secure accurate flat surfaces at a low cost, so is "chucking" specialised for the purpose of securing accurate cylindrical holes with comparatively unskilled machine attendants. "Chucking" machines, with proper outfits of boring tools, are as

FIG. 13.—*Tools used in Vertical and Horizontal Chucking Machines, Plate 3.*



a. Short and Strong Twist Drill for Centering.

b. Roughing Drill.

c. Roughing Drill.

d. Boring Tool.

e. 3-Lipped Chucking Drill. $\frac{5}{8}$-inch to 2 inches.

f. 4-Lipped Boring Tool. $1\frac{5}{8}$-inch to 4 inches.

g. Shell Reamer $1\frac{5}{8}$-inch to 4 inches, with Shell Reamer Arbor.

h. Adjustable Reamer. $1\frac{5}{8}$-inch to 4 inches.

i. Shell Reamer. $1\frac{5}{8}$-inch to 4 inches, with Shell Reamer Arbor.

j. Adjustable Reamer. $1\frac{5}{8}$-inch to 4 inches.

k. Shell Reamer. $1\frac{5}{8}$-inch to 4 inches, with Shortened Shell Reamer Arbor, also Adjustable Reamer. $1\frac{5}{8}$-inch to 4 inches.

l. Facing Tool.

Chucking and Boring Tools.

(See FIG. 13.)

For Vertical Chucking Machines with 4 Holes in Turret.

1. For chucking from the blank:—
   a. c. i. j., or *b. e. i. j.*, or *a. b. e. k.*, or *a. c. k. l.*, or *b. e. k. l.*

2. For chucking cast holes:—
   d. f. i. j., or *d. e. i. j.*, or *d. f. k. l.*, or *d. e. k. l.*

For Vertical Chucking Machines with 5 holes in Turret.

1. For chucking from the blank:—
   a. b. e. i. j., or *a. c. i. j. l.*, or *a. b. e. k. l.*, or *b. e. i. j. l.*

2. For chucking cast holes:—
   d. f. i. j. l., or *d. e. i. j. l.*, or *d. f. k. l.*, or *d. e. k. l.*

For Horizontal Chucking Machines with 4 holes in Turret.

1. For chucking from the blank:—
   b. e. g. h., or *c. g. h. l.*, Machines with rest.

2. For chucking cast holes:—
   d. e. g. h., or *d. f. g. h.*, Machines without rest.
   e. g. h. l., Machines with rest.

For Horizontal Chucking Machines with 6 holes in Turret.

1. For chucking from the blank:—
   a. b. e. g. h. l., or *a. c. g. h. l.*

2. For chucking cast holes:—
   d. e. g. h. l., or *d. f. g. h. l.*

much a part of a modern engineering equipment as are milling machines with their outfit of cutters and arbors. One prominent English manufacturer told the author that the introduction into his works of a chucking department revealed the fact that he had never before made holes that could be called round. The best system calls for a series of tools, usually varying in number from 4 to 6 for each diameter, the final operations in most cases being performed by an adjustable reamer which takes out about 0·004 inch, Fig. 10 (page 21), all holes being tested by the inside limit gauge, Fig. 1 (page 12).

For cast-iron, when parts are not too light weight, the vertical machine is best adapted, Fig. 11, Plate 3. One operator can in most cases attend two machines. Other operations, such as facing and turning, are often to advantage combined with chucking work. For steel work where oil is used and light parts or parts with a long hole, the horizontal machine is better adapted, Fig. 12. As in many other operations which are specialised, comparatively unskilled labour can be employed, but the highest skill is required to supervise and keep machines and tools in proper working condition. The tools ordinarily used consist of under-size twist-drills, boring tools, three-lipped chucking drills, four-lipped boring tools, roughing reamers, finishing reamers (adjustable) and facing tools; a part or all of these may be used, in accordance with the work and available machines, Fig. 13 (pages 22 and 23). The best shop organisation demands a department equipped with chucking machine, tools and gauges, to which every part within the scope of the department should be sent. The results are a reduction in the costs of boring, a higher degree of accuracy, and the attainment of interchangeability.

With a proper outfit, holes up to 3 inches diameter can be easily finished by comparatively unskilled workmen, to within from 0·0005 inch to 0·0010 inch of standard size.

Turning.—The lathe has been and will continue to be one of the most important machines in the equipment of an engineering establishment. The principal improvements in design to be noted in the modern lathe are quickness, ease of manipulation, and rigidity.

There is also a growing appreciation of the value of a lathe possessing the best quality of workmanship, even when used for comparatively rough work. Referring particularly to light lathe work, recent developments in other machine tools have taken away from the lathe a large amount of work for which it was formerly thought that this machine was indispensable. Except in special cases, the boring of holes is now largely relegated to the chucking department. The accurate finishing of plain parts, and, in many cases, of parts of considerable complication, is done in the grinding department. Where repetition, even of small quantities, is possible, parts up to 2 feet long and 2 inches diameter, are sent to the turret machine department. It is now recognised that it is poor economy to make a polishing bench of a fine screw-cutting engine lathe. It seems pretty well assured that in the future the lathe will be largely used as a roughing-out machine. Following this line, a great deal of work can be done by unskilled labour, one man keeping two or three lathes in operation. Stiff lathes, fitted with double tool post and with pump and pans, so that the work can be flooded with soapy water, are found to be as a means of reducing parts much cheaper than smith work. For instance, soft machinery steel spindles can be reduced $3\frac{1}{2}$ inches in diameter at one operation by means of two cutting tools, which would have a feed of about 0·007 inch per revolution. Table 2 (page 26) is interesting as showing possibilities in this direction.

It is in many cases one man working three pieces in the lathe department *versus* three men working on one piece in the forge shop. All the modern innovations which are either supplanting or improving lathe work, such as chucking, grinding, screw-machine work, polishing and roughing, are accompanied by a reduction in costs of manufacturing, the employment of less skilful machine attendants, an increase in the number of machines that one man can attend and better work. It should be mentioned that the various processes of treating turning tools may revolutionise lathe construction. Speeds, feeds, and strains must all be recalculated. Cutting speeds from 80 feet to 120 feet per minute are now quite common. Where the lathe is used for roughing out, from 0·006 to 0·008 is sufficient

TABLE 2.—*Tool Speeds for Cutting Soft Steel, etc.**

No.	Material.	Diam. before turning.	Diam. after turning.	Depth of cut.	Revs. per minute.	Cutting speed, feet per minute.		Feed per minute.	Feed per rev.
						At outer circumference.	At bottom of cut.		
		inches.	inches.	inch.		feet.	feet.		
1	Soft machinery steel.	5 1/4	1 3/4	1 3/4	27	37·1	12·25	3/16	0·007
2	" "	1 9/16	9/16	1/2	297	121	43·5	1 3/4	0·006
3	Tool steel	3 3/4	2 3/4	1/2	30	29·4	21·5	5/16	0·010
4	" "	2 1/2	1 5/8	7/16	45	29·4	20·25	7/16	0·010

No.	Material.	Original Diam.	Depth of cut.	Revs. per minute.	Cutting speed, feet per minute.	Feed per minute.	Feed per rev.	
		inches.	inch.		feet.			
5	Cast iron.	4 1/4	1/8	37	41	3 1/8	0·085	Roughing cut.
6	" "	4 1/4	1/32	100	111	3 1/2	0·035	Finishing cut.
7	Soft machinery steel.	4 3/4	3/32	23	28·5	1 7/8	0·081	Roughing cut.
8	" "	4 3/4	1/32	63	78	2 1/2	0·04	Finishing cut.

* "American Machinist," 29th September 1900.

to leave for finish grinding. Roughing limit gauges are useful for this work.

A summary of the latest practice in connection with lathe-work would include the following:—

(1) Chucking or boring transferred to the turret chucking machine.
(2) Finishing transferred to the grinder.
(3) Repetition work (even for a dozen pieces) transferred to the screw machine.
(4) Polishing transferred to a separate department.
(5) A great deal of forge work transferred to the "roughing out" lathe.
(6) Castings like hand wheels, flanged or grooved pulleys, bevel wheels, etc., transferred to the circular milling machine.
(7) A great increase in cutting speeds.

Polishing.—The establishment of a polishing department is apparently a custom more honoured in the breach than in the observance by most engineering works, even where this work could be specialised to good advantage. A well-arranged polishing department is one of the best examples of simple organisation that could be selected, for the reasons that its equipment is cheap, costs of operations are reduced, and quality is improved. This work only needs to be classified. Let any manager walk about his shops and observe polishing operations going on here and there. It is most probable that they are being done by skilled turners or fitters on expensive machines, when the work could be done by a comparatively unskilled hand with an inexpensive apparatus. A gain would also be realised in time of operation and quality of finish, if all polishing was done by men trained by constant practice. The downfall of many an accurate engine-lathe could probably be traced to surplus charges of emery, administered by the combined turner and polisher. A comparatively cheap and simple apparatus for removing dust from the polishing department would probably have the effect of inducing better grade men to become interested in this class of work, which is important both in respect to the quality and appearance of finished parts.

Gear Cutting.—The advocate of cast gears has few arguments as far as costs are concerned when confronted by the results of modern automatic gear cutters. Every form of gear cutting can now be done on automatic machines. One operator can keep from three to five automatic spur-machines and from three to ten automatic bevel-gear cutters at work. The latest practice in gear cutting is really confined to the following latest designed machines; fully automatic spur-gear cutters, with rapid return stroke to cutter spindle carriage and accurate dividing mechanism, which in some cases cut up to five teeth at once; the fully automatic bevel-gear planing machine and the fully automatic bevel-gear milling machine which develop theoretically correct teeth (one operator attending up to ten machines); the spur-gear shaper and the modern rapid cutting worm-gear cutter, in which the taper hob is used. Accurate cutters are comparatively cheap; means for testing the accuracy of finished gears are simple and cheap, but are not often seen in modern shops. Even in large shops this department is not sufficiently specialised. Gear cutting is an art, and calls for special study if accuracy and cheapness are to be combined.

Turret Machines.—The leading characteristics of the modern screw-machine or turret lathe is its adaptability for comparatively short runs. Largely on account of this feature, it is rapidly encroaching on the field formerly held by the lathe. The lack of skill and training in properly maintaining and using turret machine tools is the greatest obstacle to its more extensive use in all classes of manufacturing, both of the automatic and hand type. It is pre-eminently the machine demanding the brains and skill of the high grade tool-maker, a functionary wanting in 80 per cent. of our engineering establishments. A large amount of lathe work now done by skilled men is sure to be shortly done on the turret machine by comparatively unskilled attendants who will eventually beat the trained turner, in respect to output, accuracy and uniformity.

This applies to work like studs, bolts, cast-iron and brass parts. Where a good tool-maker is available, it pays in many cases to set up the turret machine for, say, twenty parts when operated by hand and for several hundreds when the machine is fully automatic. The author is aware that in many cases the turret machine has been and is a failure in competition with hand labour on simple machines, but he is sure that this is often where a low standard of workmanship exists and where interchangeability is practically unknown. In brass goods, especially, the demand for cheap work is rampant and, of course, the supply it not wanting. The introduction of the best class of turret machinery would assist to put on the market a superior article at very little if any advance over the rubbish now sold, where the loss of even the simplest part necessitates the purchase of an entire apparatus, so little is interchangeability practised. The great advantage in the modern turret machine lies in the possibility of using operators who, in a few weeks, can turn out accurate, uniform work in competition with lathe hands who have served several years apprenticeship. The common disadvantage to the modern turret machine is the lack of tool makers, who are necessary for keeping machines in good working condition, and the almost universal want of understanding on the part of employers of the value of such men, no matter what wages they may command. For this reason turret machines, which are an unqualified success in one shop, are often condemned as useless in another.

The variety of turret machines, both hand and automatic, is large; simply to enumerate them would require too much space. Different types have been dealt with in the recent Paper by Mr. Ashford.* The subject is an important one, and in spite of that which is a bugbear to many manufacturers—investment in tools—these machines are slowly but surely encroaching on the field now so largely held by the plain lathes operated by skilled turners using, in most cases, simple tools.

The Vertical Boring Mill.—The loss of time and the inconvenience suffered in many shops by the want of a vertical boring mill is considerable. In many respects this machine is nothing more than a surfacing and boring lathe "stood on end." When fitted with a turret slide it forms a machine whose virtues are too little known. Like its horizontal prototype, it suffers from the lack of care on the part of intelligent tool makers. With properly arranged tools its field of usefulness is very large.

---

* Proceedings 1901, page 259.

The small type of machine with 27-inch or 30-inch face plate and turret slide is especially adapted for chucking operations, for the boring and accurate finishing of holes to limit gauge, and also for facing operations. Work is rapidly chucked, the successive tools are quickly brought into play, and one man can, in most cases, attend two machines. For general work, the vertical mill has the advantages of extreme rigidity and the ease with which work is set and held in place. With these features heavy cuts are possible, and inaccuracies do not occur on account of "overhang." It is practically impossible to construct a horizontal machine with spindle surfaces and face-plate rigidity that can compare with the vertical mill. It is now made with nearly every feature common to the lathe where a tailstock is not required; it is adaptable for boring, facing and turning, and is provided with full sets of change gears for thread cutting. It is not infrequently the case that one vertical boring mill does the work of two facing lathes, whilst giving more accurate work and effecting a considerable saving in shop space.

Drilling and Jig Work.—Drilling is prehistoric as a mechanical operation, and still flourishes in its primitive glory in a great many manufacturing establishments, as far as equipment of machines and tools is concerned. As previously mentioned, a large manufacturer recently told the author that on going into the matter of adopting limit gauges and a modern set of chucking or boring tools, he found that a round hole was not made in his works. Like many others, he had never thought that "drilling" was a class of work which should be specialised as much as milling, turning or any other operation. In many shops where it would be found profitable to overhaul the drilling department, one would find (1st), the cheapest machines that can be bought having power enough to revolve the spindle when boring the maximum hole of their respective capacities; (2nd), the cheapest drilling tools that can be purchased (or forged); (3rd), a total absence of jigs or sets of tools, even when parts are made in quantities or accuracy is desirable. Strictly speaking, to do work better than "good enough" is wasteful, but it is surprising to what an extent the nominally "good enough" principle alone rules, even in the many shops where the best class of drilling would be cheapest, all things considered. The many advocates of the cheap drilling machine would do well to note that it is economy to do better work in drilling and boring than is commonly supposed; that cheap rough work can be done on a good drilling machine, and that good cheap work cannot be done on a cheap drilling machine.

Weight and price alone considered, there is no machine tool on the market to compare with what can be purchased in the shape of a drilling machine; this is the temptation to continue in the old way. Those who would work on modern lines must, however, consider where interchangeability and good work are called for; the far-reaching economy of having holes truly cylindrical and accurate to size; that such holes cannot be made on cheap, low-priced drilling machines, with primitive drilling tools; that it pays many times to take work away from the drilling machines entirely, and to finish holes on the modern chucking machine; that satisfactory results from jigs and fixtures, unaided by the accurate drilling machine, are out of the question: that with proper jigs and fixtures the highest class of work can be done on the good drill by the lowest paid labour, and that this means savings in the fitters' work. A good deal of work formerly thought to be only possible on the horizontal boring mill is now being jigged on the upright drill with profit, even for small quantities—drilling, reaming, facing and tapping.

The usefulness of the drilling machine is greatly extended by properly designed jigs, Plate 4, and it is in connection with such tools that the greatest benefits of the accurate drilling machine will be realised. Many jigs, however, are the merest make-shifts and are seemingly designed as rough laying-out boxes or plates, not as tools for turning out accurately finished work. What are fully as important as the jig itself, but wanting in the majority of cases, are proper boring and finishing tools. It is probably true that, except by the sewing machine, small-arms, ordnance and ammunition makers, the economy of the drill-jig is, with but comparatively few exceptions, little understood; perhaps this accounts somewhat for the continued prosperity of the makers of cheap drilling machines. There are surprising results awaiting those who have not looked into the details of their drilling work.

Portable Machines.—Like many other mechanical operations, portable machine work is not new, but it has recently been extensively developed in large engine works and in the manufacture of electric motors and generators. It is of course mainly applicable to heavy work, particularly of bulky or weighty parts where the surfaces to be machined are small, compared with the part itself.

For a great deal of this work it is found cheaper to carry the machine to the work rather than carry the work to the machine. Where it is most completely carried out, floor plates of large area are made use of. The General Electric Company at Schenectady have one plate 175 feet long by 20 feet 6 inches wide, Fig. 15. This is made up of sectional plates 8 feet 4 inches wide by 20 feet 6 inches long, Fig. 16 (page 34). The depth to the bottom of the ribs is 10 inches. In new works now being erected by the Allis Engine Company, floor plates 250 feet long are being made.

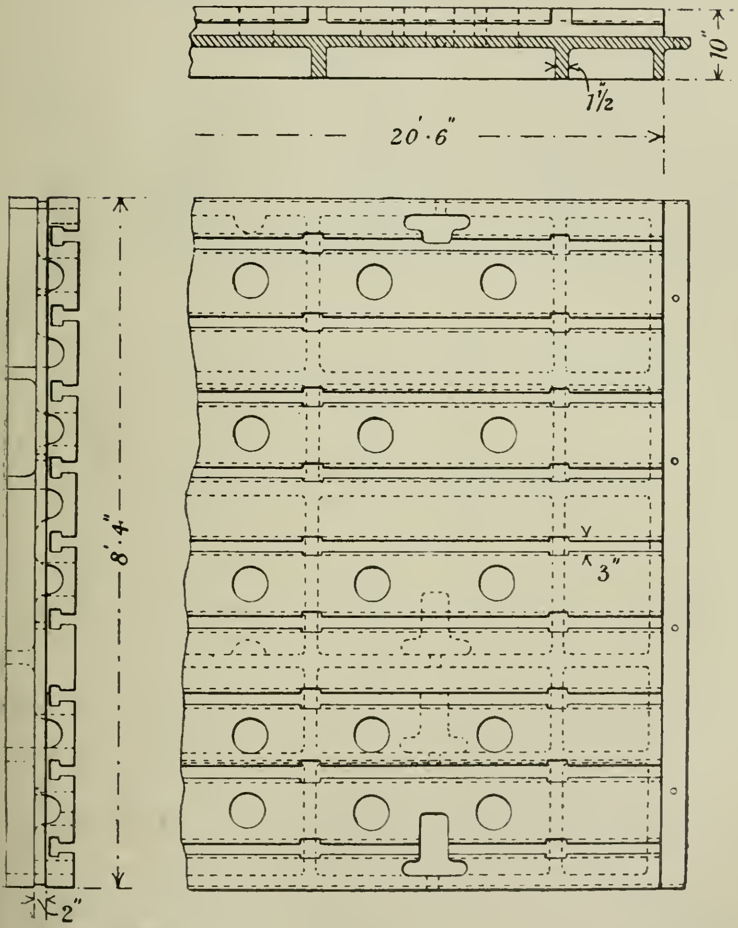
Nearly all modern portable tools for heavy work are driven with separate electric motor. They consist mainly of drilling, milling, slotting, and planing machines. All are arranged with eye-bolts so that they can be readily lifted by overhead travellers. Many of the machines are of far less weight than the parts on which they operate. The principal advantages connected with their use are:—

(1) The ease and facility with which they are transported, compared with the parts on which they are operating.

(2) A less expensive machine is possible than would be required in case it was big enough to embrace the parts.

FIG. 15.

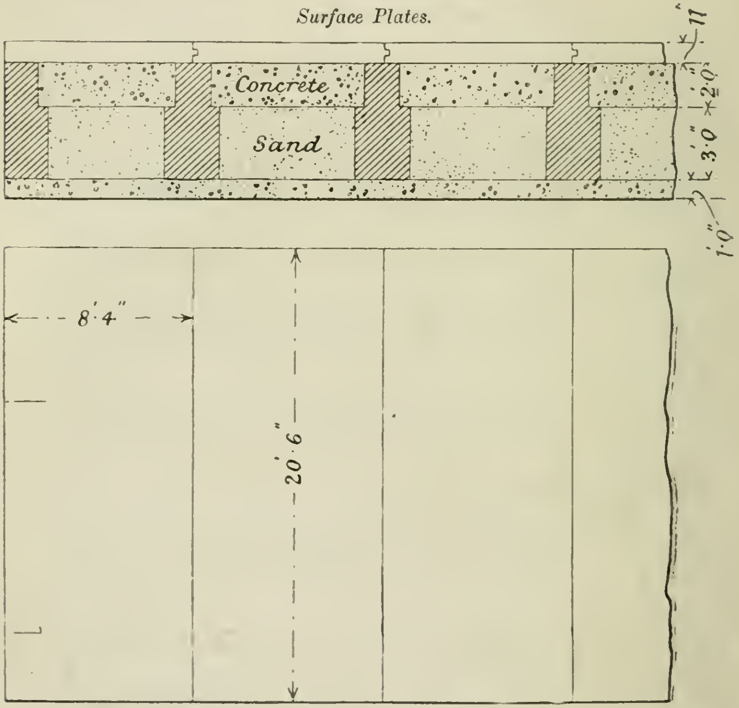
End of one section of Floor Plate 175 *feet* × 20 *feet* 6 *inches.*



(3) Tools are rarely idle, as they can be operating upon one piece while another is being set, and can be brought at once to the work.

(4) Several machines, like boring, slotting, milling, &c., can be operating on one piece at the same time.

FIG. 16.—*Foundation of Floor Plate.*



(5) Parts do not require resetting for different operations, often more expensive than the machining itself.

Small Tools.—The small tools referred to are those which are indispensable to the successful working of ordinary machine tools; for example, cutters, reamers, taps, dies, arbors, boring tools, and gauges. It is remarkable how little attention these important articles receive, even from those who are users of the best class of machinery. Many a valuable labour-saving machine tool is an utter failure, or only half a success, largely on account of ignorance in selection or care of the tools. Throughout the world there is a scarcity of tool-makers who understand these little articles. The labour-saving machine is nothing without them, yet scores of manufacturers have sunk capital in badly designed, inaccurately made, uncared for, never inspected small tools. The subject is a big one, and space allows but brief mention of the questions that the modern manufacturer should put to himself. Are the small tools of the right design, so that cuts are easily taken without too severely exerting either operator or machine? Are they well made and within reasonable limits of accuracy? Without accurate tools it is impossible to employ low-priced wages for high-grade work. Are they made of the best material, having in view wearing qualities on a particular class of work? Are they kept in the best working condition, sharp and in good repair? Output and quality will fall off if they are not. Are they "scrapped" when past their useful age? Are they cared for in well-arranged tool stores, or does each workman foster his own "kit," add to, take from, sharpen, repair and inspect? It is safe to say that many shops are stocked with ten times as many tools as are necessary, simply for the want of proper stores. One large shop recently found that two tons of tool-steel could be dispensed with by arranging tool stores, instead of allowing each man to retain his own complete outfit. Better cut down the quantity and improve the quality. Are they ever inspected? How many taps or reamers cut to size? How many arbors run true? How many teeth in milling cutters cut? How many gauges guaranteed to 1-1000 of an inch when new (note the degree of accuracy) are no longer accurate to 1-100 of an inch, are neither round, square nor oval? How many "home-made" tools are nearly as good as those that reliable makers can supply, or as cheap? Last, but not least, how many establishments have a good head tool-maker who is familiar with the latest practice, knows the best forms of tools for different classes of work, and appreciates the value of keeping tools in the best working conditions? How many take the trouble to train such men, give them the opportunity of studying what others are doing, or pay them sufficiently to induce them to put their brains and intelligence into this work which demands thoughtful application and the highest mechanical skill? Modern manufacturing cannot be carried on unaided by well-cared-for cutting tools of the best quality. The higher the output per machine and man, the greater the importance of the tool question.

Tool-Room.—By the term "tool-room" is meant an equipment of the best grade of machine tools and small tools necessary for the maintenance and supply of the special tools and fixtures, which are used for manufacturing purposes. In an old-fashioned plant this equipment might mainly consist of a forge and a grind-stone. In a highly organised plant making an extensive use of labour-saving machines, fixtures, and jigs, it must consist of the most accurate machines, such as the universal mill, engine lathes, shapers, boring machines, drills and grinding machines, and also of accurate gauges, the equipment varying in size and variety in accordance with the main plant.

It seems curious, but it is a fact, that many manufacturers do not realise that complicated labour-saving machines and tools, constituting a highly productive outfit, rapidly degenerate unless the means are at hand for constantly regenerating. They will invest in expensive machines which plain figures show are profitable, but will leave works, managers, and foreman nearly destitute as to the means of keeping up the plant. The object of fast working machines and accurate tools is to save hand-labour. Labour-saving outfits fail in a measure to replace hand-labour if accuracy is lost sight of. Cutting tools will wear, and whether they are adjustable to gauge or of fixed dimensions, the allowable limits for wear are really very small, if we expect labour-saving tools to compete with the skilled worker. The need of constant renewal is obvious. To attempt this renewal unaided by the very best appliances is uneconomical.

Many manufacturers attempt tool-room practice in a groping sort of fashion, a lathe here and there, a milling machine occasionally made use of when not employed in regular work, and a standard set of gauges purchased in an unguarded moment, and carefully kept in the office under lock and key. A few who have fairly good outfits make the mistake of turning their tool-rooms into manufacturing establishments of those articles which could be purchased more cheaply and better from a trustworthy maker. Those who proceed on this plan are liable to be constantly behind in respect to the latest design of tools, for the reason that they come so little in contact with those who make a special study of tools and the best ways of producing them.

Others have a vague sense of the need of a tool-room, but do not see that this equipment calls for everything of the best. They try to economise in the purchase of outfit, and must surely therefore only attain indifferent results. None but machines of the highest accuracy should be allowed in the tool-room. The worst offenders of all are those who try to economise the wage account chargeable to tool-room. The very best skill and intelligence obtainable should be employed in this department, for on it rests a good part of the responsibility of producing a large or small output. Whether the plant is highly productive or not depends largely upon the head tool-maker. To expect brains and intelligence of a high order to seek employment where the wages are low is contrary to all laws of supply and demand. American manufacturers, who generally recognise the value of a proper tool-room, commonly pay from 12*s.* to 16*s.* per day, and even 20*s.* per day, for good tool-makers.

Erecting Department.—Probably in no department of mechanical work are the contrasts between old and new methods more striking than in erecting or assembling. In the new method, machining is done accurately to dimensions; in the old, machine and tools are mainly used for removing metal, and reliance is placed on the fitter for proper working fits. In the new, accuracy and interchangeability of dimensions are maintained by a suitable equipment of gauges and the establishment of limits; in the old, there is a variety of sizes depending upon the skill and judgment of individuals. In the new, the time necessary for "setting up" a particular piece of work, or "lots" of work, is reduced 25, 50 per cent., and even more, below that taken in the old shop. In the new, the number of fitters is strikingly small compared with the abundance of this class of helpers necessary in works running on old lines. The model erecting department, therefore, is one in which fitters' work is reduced to a minimum, and where the least possible amount of time is occupied in assembling. These results are, of course, only possible when the best methods of machining are practised, when jigs and fixtures are used as much as possible, when a proper equipment of gauges is installed and a system of inspection is amplified.

Testing and Analysing Material.—In view of the fast machine operations, the increasing demand for accuracy and the exacting requirements in respect to material under which the engineer often has to work, it is wonderful how little the ordinary manufacturer really knows about the structure, composition, and capabilities of the material which he is continually buying, manipulating, and selling. A testing machine here and there (crude enough as a rule), a few laboratories connected with schools and scientific public institutions ; the rest is guess-work. A change of foundry foreman, or the transfer of patronage to another steel maker, often demoralises a whole establishment, results in the ruin of expensive machines and tools, and in the scrapping of costly finished product.

The advantages of possessing a well-equipped laboratory and testing department are many and far-reaching compared with the sole disadvantage—expense, and they bring quick returns for a small outlay. In the first place, raw material, pig-iron, scrap, coke, steel, copper, brass, &c., should be bought to specification. The result would be emancipation from the slavery of "brands." This is in itself a considerable advantage to the buyer. A control of cupola mixtures can also be undertaken which will give definite results in castings. Steel, iron, and other materials can be selected independently of the recommendations of the maker, who too often answers a complaint with the assurance that more expensive material must be purchased, when perhaps cheaper would be better. Not alone in the purchase of material, but in the manipulation as well, is the analysing and testing engineer of value. Castings must be properly treated, and be of the right mixtures to allow rapid and accurate machining. Recently a case came under the author's observation where the product of a milling machine was increased 30 per cent., simply by improvement in the quality of material. Many concerns are using *hard* material which is necessary for certain parts but uncalled for in other cases, because they have no definite knowledge to enable them to vary cupola mixtures. If they had, they would increase the speeds of machining in a large percentage of their work. Material should be studied with a view to selecting that which is most suitable for the purpose, bearing in mind its suitability for being rapidly machined. This cannot be accomplished with the haphazard methods commonly employed. The establishment of laboratories is confidently put forward as a suggestion worth the serious consideration of mechanical engineers. It will pay, in nearly all cases, for those employing 1,500 hands, in a majority of cases for those employing 1,000, and in some where under 1,000 are employed.

Where the size of a shop does not warrant the expenditure necessary to support its own department, several manufacturers can easily combine and contribute to the support of a fully equipped laboratory. Where the last course only is feasible, petty jealousies and nonsensical isolation, which are so prevalent amongst manufacturers, will probably stand in the way for some time to come. There is, however, no practical reason why every mechanical engineering establishment in the United Kingdom should not have a testing institution at its command which could be constantly made use of. The realisation of this state of affairs would be of incalculable benefit to the industries and commerce of Great Britain.

The following Table 3 of chemical specifications is one suitable for a large variety of light machinery castings which can be rapidly machined, are close grained, have good wearing qualities, and take a good finish.

Shop Fittings.—Good fittings play a not unimportant part in shop economics. They are too often looked upon as articles of

TABLE 3.—*Chemical Composition of Light Castings (Iron).*

	A. Mixture for thin castings under ⅝-inch thickness.		*B.* Mixture for castings of an average thickness of ⅞ inch.		*C.* Mixture for castings 1¼ to 2 inches thick.	
	Limits allowed.	Analyses desired.	Limits allowed.	Analyses desired.	Limits allowed.	Analyses desired.
Silicon	2·45 to 2·65	2·55	2·30 to 2·50	2·40	2·15 to 2·35	2·25
Sulphur . . .	0·07 to 0·10	0·08	0·07 to 0·10	0·09	0·08 to 0·12	0·10
Manganese . .	0·30 to 0·70	0·40	0·30 to 0·70	0·40	0·30 to 0·70	0·40
Phosphorus . .	0·70 to 1·00	0·90	0·50 to 0·90	0·70	0·40 to 0·80	0·60
Combined Carbon	0·30 to 0·50	0·40	0·30 to 0·50	0·40	0·30 to 0·50	0·40
Graphite . . .	2·90 to 3·20	3·10	2·90 to 3·20	3·10	2·90 to 3·20	3·00

For very heavy castings a mixture containing about 2·00 Silicon should be used, other elements same as mixture *C*.

luxury, only to be made use of by faddists instead of as possessing a practical value as means of saving time and maintaining order and cleanliness. Among the more important are included: well-designed work benches, Fig. 18, Plate 5; shop stands for workmen who are machine attendants; cans and buckets for waste and rubbish; properly designed racks for holding parts, Fig. 19; carefully arranged receptacles for tools and gauges, Fig. 17; and racks for holding rough material. Stores for rough materials, partly finished work and finished product should be most carefully studied. Simple and easy methods of fastening countershafts and main shaft hangers should be devised, Fig. 24, Plate 6. Means of transportation—whether cranes, railways, or trucks—should of course receive special attention. Machine-shop floors deserve far more thought than they usually receive, Fig. 20, Plate 5. Means of heating and ventilating, Fig. 23, Plate 6, are, as well as floors, absolutely essential to the modern shop, for without them it is impossible to properly keep fine machines, tools, and gauges in good condition. Comforts and conveniences for workmen are fast becoming necessities in the modern shop, as they help in attracting and retaining the best and most intelligent workpeople, Figs. 21 and 22.

Organization.—Most shops, even the newest, are in a way organized without much analysis or systematic study of the latest methods. Volumes have been written on shop organization, and there is room for more volumes. Every item, which it is proposed to mention here, is capable of being expanded into a separate treatise. The main items which must receive attention from the modern manufacturer are as follows:—

(1) The adoption of the most economical methods of manufacturing, and machines best adapted to the product, as well as the best forms of small tools and proper gauges.

(2) The specialization of manufacturing operations both in respect to equipment and supervision. This is largely regulated by the quantities that are to be made. Where the quantities are small, different parts must go through the same sets of machines. Where transportation would be costly on account of weight of parts or

the quantities are large, separate parts may command a complete outfit. Care should be taken not to have too many machines or varieties of work under one foreman. Many successful manufacturers state that no foreman should have charge of more than forty to fifty men.

(3) The placing of departments in the best positions relative to each other, so as to facilitate transportation and progress of work.

(4) The possession of shop fittings and structural features best adapted to the product and to the comfort and convenience of the workpeople. How far an investment in this direction will pay cannot always be shown in cold figures, but the recognition of its importance is growing, and several modern manufacturers have installed elaborate arrangements without the slightest claim to philanthropic motives in all that they have done for their employees.

(5) The installation of a system of inspection by which quality of product is kept within desired limits. This is strangely and commonly neglected, but it naturally follows the adoption of modern machining operations which are largely performed by unskilled men, using the best forms of cutting tools and gauges and producing interchangeable work. "Every foreman his own inspector" is no longer workable in the modern shop.

(6) The adoption of methods by which exact costs of product are known and work in progress is constantly under control. "I fear no competition except from those who do not know what their work costs them," said one manufacturer. "I try to make a date of delivery gospel," said another. Needless to mention both the above are rare specimens of shop managers.

(7) The establishment of a system of training and instructing employees. Most manufacturers work on the Micawber principle of waiting for "something to turn up" in the way of skilled employees. This is slipshod, unsatisfactory, and shortsighted. It is the natural concomitant of badly equipped, poorly arranged, comfortless, and low-waged establishments, having no features of equipment or management sufficiently attractive to retain an intelligent, self-respecting workman after he is well trained.

(8) The best selected plant is often but a partial success, and not infrequently a total failure, for the reason that it is put down without sufficient consideration in respect to organization. The author is being repeatedly told by manufacturers that certain machines which he knows are effective labour-savers in constant operation would simply be smashed to pieces if they tried to put them to work. This might occur, chiefly for the reason that their shops are arranged utterly regardless of the fact that it pays to specialise operations, to group machinery according to the nature of the work, putting over each group a competent foreman who thoroughly understands the class of work which he is supposed to supervise. The majority of shops, in their effort to eliminate high-waged employees (always the most profitable), employ too few foremen. They put one man over too great a variety of work and give him too many men to supervise. From forty to fifty men is the ordinary limit for a good foreman. Many shops have one foreman in charge of as many as 150. He must be a combined expert in turning, milling, planing, grinding, etc., do his own tool making, cost keeping, and inspecting, all for 50*s*. a week. This is an incomprehensible situation, no matter what salary may be paid, demanding an experience and training impossible of attainment in these days of "second splitting" operations performed on highly developed machines. Specialization of operations, as well as of product, is necessary for the most economical manufacturing. When work is classified in accordance with the best practice, namely having its plant arranged with a view to a thorough supervision on the part of foremen, and having an orderly progress of parts, cheaper and better work will be the result, and responsibility can be more easily located in the case of mistakes.

Extensive Application of Modern Methods Possible.—There is a widely spread and erroneous idea, particularly amongst European manufacturers who would emulate American manufacturers, that the latest methods cannot be economically adopted except where work is thoroughly standardized, specialised, and made in large quantities. Advantage of every method which has been mentioned, with the exception perhaps of jig and fixture work, can be taken where none of the above conditions exists, not even excepting that which practically amounts to interchangeability. One hole is more cheaply bored in a chucking machine than in a lathe. It is more easily made to a limit gauge than when the skill of a workman in setting his calipers has to be trusted. One spindle is more cheaply finished in the grinding machine than in the lathe, quality duly considered, and again is more easily finished to a limit gauge than to calipers, with the employment of less skilful labour. With the quickly adjusted, easily manipulated milling machine, any amount of work can be more cheaply milled than planed, even where only a few pieces are to be worked. Inspection, good equipment of gauges, tool stores, the latest machines and small tools are necessary, whether one piece or 1,000 pieces are in question.

The idea that big quantities and standard work are necessary before modern equipment begins to play an important part in the economics of manufacturing is the delusion of those who have grasped but a small part of the problem.

Apprenticeship Question.—Unquestionably one of the most serious obstructions to the introduction and successful working of new machines and methods is the lack of knowledge and understanding of modern machine methods on the part of workmen. This is not due so much, as is commonly supposed, to the restrictions and regulations of trade unions, as to the ignorance, bad management and want of foresight on the part of the masters. The fact is that men in a great many shops accomplish wonders, considering the opportunities given them to learn and the appliances with which they are expected to work. Within a comparatively short time, methods of manufacturing, machines and tools, have undergone an almost revolutionary change. This change has been so great and rapid, that men who served as apprentices under the old *régime* are ignorant of new methods, and have not the necessary training to manipulate successfully and supervise the most economical working machinery. Many of them are as much at home in a really modern shop as "Alice in Wonderland." It is not at all surprising that they shake their heads at strange new machines and doubt the tales of the American "Mad Hatter." It is well to ask the masters who grumble if they themselves are familiar with the latest methods of machine work; if they are familiar with the advantages of the subdivision of labour and departmental work; if they know the value of skilful, intelligent tool-makers, and are familiar with the best machines and appliances. These are items which must be studied by the masters and, side by side, should be considered: how shall they instruct and train men in the proper use and care of machines and tools? In other words, systems of apprenticeship must be inaugurated and maintained which teach men how to work in modern ways. Do not work apprentices on old-fashioned machines with out-of-date tools, letting them take years to learn to perform certain operations which a man from the street with three weeks' practice can do better and quicker on a modern labour-saving tool. Many shops are having endless trouble from trying to work new machines by men trained on the old lines, neither masters nor men comprehending their duties. It is the duty of masters to establish modern systems of apprenticeship arranged in accordance with new methods. It is the duty of men to try to adapt themselves to these new systems. It is wasteful and foolish for all to insist that a man must serve from four to five years before he can become a proficient turner, when we know that in a few weeks a labourer can learn to operate two grinding machines and produce cylindrical surfaces that it is impossible for the most skilful turner to duplicate, either in regard to quality or cheapness. This is not saying that it is unnecessary to train men to become good turners; it is, however, unnecessary to train them to perform many operations which are superseded by new methods of working. The same comparison can be made between the screw machine and the lathe, and the milling machine and the planer. Chuck and jig work supersede boring and drilling. Men must realise that the new ways have come to stay. Masters will wait in vain if they think the technical school can ever take the place of rational training in that best of all schools, the shop itself. Many employers are beginning to realise that there is but one way to get good men, that is, to make them. A modern system of apprenticeship naturally divides itself into three broad classes :—(1) Training of men who wish to become skilful in special operations like turning, planing, etc. (2) Training of men who wish to become merely machine operators. (3) Training of men who are necessary for supervising and keeping plant in a high state of efficiency. By the old methods, men are largely trained to become skilful in turning out a certain product. By the new methods, the highest skill is employed as supervisor of labour-saving machinery which turns out the product in a practically finished state. This calls for a radical change in the systems of apprenticeship.

Politicians and writers are raving over the technical schools of Germany. Speaking as one who has for years been in contact with the product of the German technical school, the author has no enthusiasm nor admiration for their methods ; at least, as far as mechanical progress is concerned. Technical education as taught to-day is useless except to a very small percentage of our mechanical workers. There is an immense amount of talk about scrapping old machinery, buying new plant and planning new shops, whilst the most important factor of all—men—is left to shift for itself. Yet all are asking the question where can I get good men ? Train them, is the answer. The means for doing this are in the hands of every manufacturer. In your own shops, on your own machines, with your own instructors, in your own time ; neither municipalities nor governments can do it for you. Manufacturers must establish systems of apprenticeship which include workshop experience under educational guidance.

Plate 6 shows three illustrations of shop features which are taken from one of the most recently erected machine-tool establishments. These are given to call to mind features which do not usually receive attention, but which are being more and more recognised by modern manufacturers as economic factors of shop organization.

The Paper is illustrated by Plates 1 to 8 and 8 Figs. in the letterpress ; and several examples of machine work were exhibited at the Meeting, Figs. 32 and 33 (page 47), and Plates 7 and 8.

Discussion on 17th January 1902.

The PRESIDENT expressed his belief that the Paper brought forward a large number of points in workshop practice, which demanded the most careful consideration of Mechanical Engineers at the present time. It also brought forward points on which it was quite legitimate to hold more than one opinion, and it therefore gave all the elements for a good discussion. He expressed the thanks of the Institution to the author for the Paper, and for the trouble he had taken in bringing such a large number of samples of work done on the various machines, Figs. 32 and 33, and Plates 7 and 8.

Samples of Grinding Work exhibited at Meeting.

FIG. 32. *Small parts, full size.* (Brown and Sharpe.)

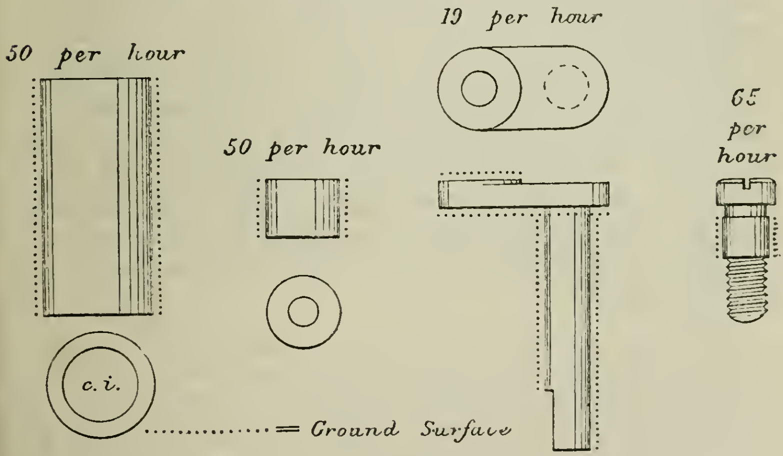
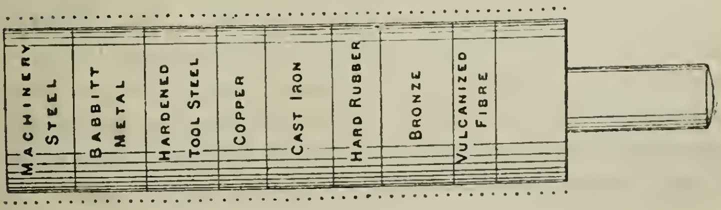


FIG. 33.
Cylinder of Various Materials. (Landis.)



Mr. **Orcutt** drew attention to the large field covered by the title of the Paper, and the difficulty of arranging the matter so as to deal with the many subjects. He had been obliged to cut down the matter, in order to keep it within compass. His aim had been to make the subject as far as possible practical and not too theoretical, and in selecting the items which made up the Paper he was guided, firstly by the importance of factors in the production of good and cheap work; and, secondly, by those things which his own experience showed him, generally speaking, did not receive sufficient attention. Many things had to be omitted, such as systems of rewarding labour, especially the premium system which was now receiving a great deal of attention. There was present at the meeting one of the best exponents of that system, and he hoped Mr. Rowan would give the members the benefit of his ideas on the subject, which was an important and far-reaching one. Cost-keeping, which went with the premium system, trade union troubles, masters' combinations, economics, and social life, were all subjects affecting workshop practice directly or indirectly, but it had been impossible to deal with them. In attempting to cover a large field it had been necessary to make general statements, and general statements were open to misinterpretation, as in many cases they were without explanation or qualifying details, and he asked the members not to forget those facts.

Mr. J. **Hartley Wicksteed**, Vice-President, pointed out that there was a paragraph in the Paper comparing the output of heavy milling machines with the output of planing machines, in which it was stated that the author had known of cases where the operation of heavy milling effected a saving of 75 per cent. in time. A particular case, which the author gave as an illustration of profitable milling, was that of roughing out lathe-beds. The lathe-bed illustrated in Fig. 7, Plate 2, was one with V's upon it and was a small lathe-bed, although it was a so-called heavy milling machine. If those beds had to be turned out in duplicates, there would be a great saving of attention to the machine in having a milling cutter properly arranged to plane the V's at the proper distance apart. An ordinary English lathe, however, was not made with V's, but with flats, and he wished to make a little comparison between what could be obtained from a good English planing machine on an English lathe-bed, and what could be obtained in planing flat surfaces by the milling machine. It was possible to plane with a planing machine ten superficial feet per hour with one tool box, and it was not necessary to run the machine more than 22 feet a minute, which enabled lathe-beds of good hard metal to be planed. It was not necessary to make them of soft metal for the purpose of saving the tool. If that was run out, it might be thought that he was allowing for a very coarse feed, but that was not so; he was only allowing for a feed of $\frac{1}{8}$-inch, which was not coarse in comparison with many of the feeds seen in the work exhibited by the author. He was, however, allowing for cutting both ways on the planing machine, because there was no reason why, when planing a plane surface like a lathe-bed and other things, the driving power, wear and tear, and time in running the machine back, should be wasted with an idle stroke. It was perfectly simple and easy to make the planing machine cut both ways. By doing so, he had found that it was possible to rough over and leave an approximately true surface at the rate of ten superficial feet per hour with one tool-box. On a heavy milling machine, say a lathe-bed with two faces, each six inches wide, a foot of width was planed, although the milling tools might be 20 inches wide, that was to deal with certain seatings on the end parts; the main part of the work was a foot wide. If the milling machine was proceeding with a feed of 3 inches a minute, it would take four minutes to mill a superficial foot, which worked out at 15 superficial feet per hour. As he had said, it was possible to plane with one tool-box 10 superficial feet per hour, but in planing a lathe-bed there would be two tool-boxes on the cross-slide, and therefore the lathe-bed would be planed at the rate of 20 superficial feet per hour.

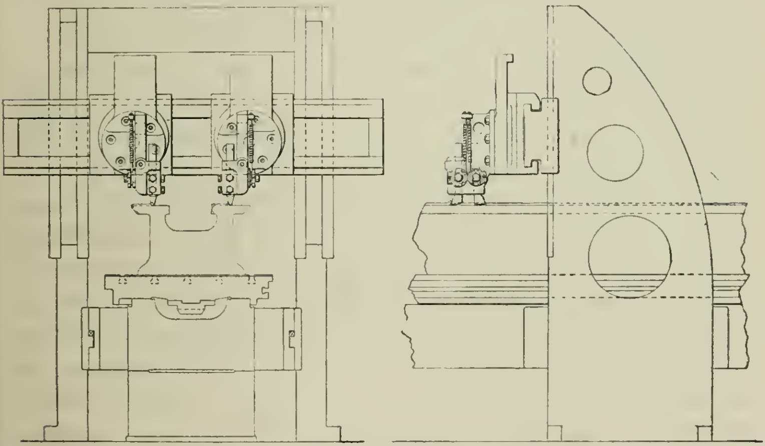
There was another rather important difference between the principle of milling and planing. A milling tool approached the work across its face, and if it encountered a small amount of work to remove, say one-quarter of an inch, the machine would spring less

(Mr. J. Hartley Wicksteed.)

away from the work than it would do if it encountered half an inch or three-quarters of an inch. Where it encountered more work to remove it would spring more, and the surface it would leave would not be approximately true. The planing machine tool cut chiefly on its side; it was cutting along a furrow. The point of the tool was uniformly stressed in an upward direction, but when it came to a deeper part of the furrow it received more pressure laterally and sprang more sideways, but not from the finished surface of the metal. Therefore, after the roughing cut, the work would be more approximately true from a well-formed planing tool or tools than from milling tools. But in proportion as the roughing cut was approximately true, the next cut would be more or less true. If there were sensible irregularities in the roughing cut, there would be microscopic irregularities in the second cut. So much was that the case that, if the roughing cut was not fairly true, it would be necessary to take three cuts before obtaining a true surface. He did not share the view which appeared to be taken by the author in speaking of the planing machine as being superseded by the milling machine. He had taken a case out of the Paper wherein a case could be made out for the planing machine. He exhibited a double cutting tool box, Fig. 34 (page 51), to show how two tools could be conveniently held in any strong planing machine, and cut both ways with an over-run of not more than six inches. But in dealing with heavy work—armour-plates for instance—which had to be planed all over the surface, there were many planing machines in England in which there were two cross-slides facing each other, in each of which there were eleven tools, so that the planing machine had as many cutting edges as the milling machine. A similar arrangement of a large number of tools closely set together was used for planing the side plates of locomotives. There were thousands of tons of plates planed every week for all kinds of purposes, ship-building, boiler-making and bridge-building; those plates came from the plate mills varying at the edges a good half-inch. Some parts of the plates would only just finish to the requisite width, while other parts would have half an inch of stuff to remove. The planing of plate edges was done on a very large scale indeed, and what was called in the Paper rotary planing machines had been made for the purpose of planing the plate edges. A large number of plates were cramped on a table, and rotary cutters were made to revolve and reduce the stuff off the edges. Heavy milling machines weighing 60 to 70 tons had been also made for edge milling. But the great bulk of the work of planing plate edges today was done by planing and cutting both ways. People had tried the other, but the very people who had had a fancy for the other and had given it a fair trial, when buying new machines went back to the planing tool and planing both ways. The reason was not altogether the difference between planing and milling, but partly that in order to make the milling at all economical, it was necessary to have a bunch of plates four or six inches high operated upon simultaneously. To adjust those plates one on top of the other, so as to clean up all the way along, takes longer than doing the plates one at a time, and for that reason nearly all the plates planed were planed one at a time with double cutting tools on planing machines.

FIG. 34.

Double-cutting Tool Boxes for Planing Machine. (Buckton and Co.)



Mr. JAMES ROWAN thought the first paragraph of the Paper gave a correct statement of the direction in which engineers of this

(Mr. James Rowan.)

country were now tending. There was no denying the fact that machine work was rapidly taking the place of handwork, and although there was practically nothing new brought forward in the Paper, yet there was a very clear indication of the methods which should be adopted by manufacturing engineers. The use of gauges and grinding he looked upon as two of the leading features of the Paper. Limit gauges had not been used until lately to any great extent, but now they were being rapidly adopted, and the use of them could not do otherwise than help to produce good work. Grinding was also being rapidly adopted, and in many factories would prove a valuable addition to the turning lathe. The tool-room was another modern machine method which was rapidly being adopted, and rightly so; testing and analysing of materials by private firms would in the course of time be largely adopted. All these improvements did not come at once; they came slowly but surely. There were many workshops which had adopted quite a number of the modern machine methods mentioned by the author, and these shops were rapidly increasing in number. The author had, in many respects, unequalled experience, and had had a careful training; no one was better acquainted with the subject of modern machine methods than he was, and so long as he confined himself to general statements he excelled. In many instances, however, he had condescended to figures and statements which were surprising. For instance, the author spoke (page 16) of the heavy milling machine having "the advantages of requiring little attendance and of turning out work two or three times faster than the planer;" and later went on to say (page 17) "The planer is a much neglected, long-suffering machine, too often found in such dismal, unfavourable quarters that any attempts to improve either the accuracy or quantity of its product would be of little avail. Daylight and good foundations are commonly wanting in the planer department." Then further on the author said (page 18) "There is an immense amount of planing being done at cutting speeds of from 12 to 18 feet per minute which could be done at the rate of from 20 to 25 feet per minute"; and later on (page 30) "It is not infrequently the case that one vertical boring mill does the work of two facing lathes, whilst giving more accurate work and effecting a considerable saving in shop space." A statement was no proof, and when the author stated that milling work could be done two or three times faster than in the planing machine, it required to be qualified by surrounding circumstances. As a matter of fact, in general work he himself would question this statement altogether. It was hardly right to quote exceptional cases and advance them as averages. The planer was not a much neglected, long-suffering machine; the planer was a good machine, and was often as well located in workshops as other machines. It was not the speed that controlled the output of the machine; it was a combination of feeds, speeds, and depth of cut, and in giving the capacity of a machine for doing work these elements should be taken into account all together. The question of doing work on different machines was a comparative question. The cheapest way was the right way, provided the work was equally good, and before determining which was the cheaper way, very accurate cost-keeping was required. It was often the want of accurate cost-keeping which deceived people as to the cost of producing articles. Again, consider the two machines: the vertical boring mill and the surface face lathe, if they were of the same size and both powerful enough for the work to be done, could be run at the same speed, and the same feed could be taken of each; there was no saving to be gained beyond the fact that, if a job required to be lifted into the machine by a crane, it was lifted on to the vertical boring machine and the crane removed, while on the face lathe the job required to be hung by the crane until it was fixed up and set to some degree of accuracy. It was in this that the boring mill had the advantage over the facing lathe; but any engineer would hardly credit that the boring mill would do double the work of the face lathe. No more accurate work could be produced in the one than in the other, and the one occupied as much floor space as the other. With modern machines the cost of the erecting department would be greatly reduced. Not only should the cost of that department be greatly reduced, but infinitely better work should be produced.

The author had enumerated the fittings which tended towards shop economy, but even in that it was necessary to be careful.

(Mr. James Rowan.)

Workshops have been built in America and other places, magnificent monuments to the capital at the disposal of the designer, but altogether disproportionate to their output. Buildings had been erected which might stand for a thousand years, and the lavatories and conveniences for the men were so numerous as to be altogether unnecessary. In one large workshop in America, built a few years ago, one washstand basin was provided for every man. The latest addition they have made provided one washstand basin for every ten men. The author also referred to the number of men under one foreman, but the speaker could not understand how any foreman could take charge of even 40 or 50 men. Then the author was good enough to take it for granted that a foreman in this country with 150 men under him received a salary of 50*s.* per week; inquiries would show the author that he was entirely wrong in that statement.

Towards the close of the Paper (page 43) the author wrote as if the manufacturers in this country were not in the same street with the American manufacturers. A friend of the speaker's who visited America in the summer of 1898 wrote: "After all I have not seen a place in our own line of business which is better equipped with machine tools or buildings than our own." That was written by a marine engineer, and similar statements were made in other letters. It would be found that in any well managed modern workshop with good tools the tendency would be to standardize work. Big quantities of similar articles were not necessary; in fact in some businesses, such as the manufacture of marine engines, they were impossible, yet it was quite possible to standardize marine engines, and it was now being largely done. The tendency would also be to allocate work of a similar description to definite machines. On the other hand, if standard work was being produced in a well managed modern engine factory, the tendency would be to provide special machines for doing the work. The author had left out a great many points which might have been introduced with advantage; but no purpose would be served by referring to them now. The principal element, that is, the human element, might have been more efficiently and more clearly dealt with.

With regard to the apprenticeship question, he considered the author had gone off the lines a bit, and that a little study of the question would satisfy him that the apprenticeship arrangements in this country, as far as engineering was concerned, were very good. There was one feature in the Paper which Mr. Rowan could not help referring to, as it permeated the whole of it. He took it that the author in speaking of manufacturers, and employers, and workshops, referred to those of this country, unless otherwise mentioned; it was the absolute want of knowledge of modern machine methods of workshop managers. The author could not refrain from expressing his complete confidence in American manufacturers and workmen. A few examples might be quoted from the Paper, amongst others (page 27): "Let any manager walk about his shops and observe polishing operations going on here and there. It is most probable that they are being done by skilled turners or fitters on expensive machines, when the work could be done by a comparatively unskilled hand with an inexpensive apparatus." "The lack of skill and training in properly maintaining and using turret machine tools is the greatest obstacle to its more extensive use in all classes of manufacturing, both of the automatic and hand type. It is pre-eminently the machine demanding the brains and skill of the high grade tool-maker, a functionary wanting in 80 per cent. of our engineering establishments." Further on the author says (page 30): "In many shops where it would be found profitable to overhaul the drilling department, one would find (1st), the cheapest machines that can be bought having power enough to revolve the spindle when boring the maximum hole of their respective capacities; (2nd), the cheapest drilling tools that can be purchased (or forged); (3rd), a total absence of jigs or sets of tools, even when parts are made in quantities or accuracy is desirable." Then later on (page 32): "It is probably true that, except by the sewing-machine, small-arms, ordnance and ammunition makers, the economy of the drill-jig is, with but comparatively few exceptions, little understood." Later on (page 36): "Many manufacturers do not realise that complicated labour-saving machines and tools, constituting a highly productive outfit, rapidly degenerate unless the means are at hand for constantly

(Mr. James Rowan.)

regenerating. They will invest in expensive machines which plain figures show are profitable, but will leave works, managers, and foremen nearly destitute as to the means of keeping up the plant." The Paper was teeming with paragraphs such as these. It might be granted that many of the sad conditions which the author deplored existed; some of them might be found in one shop and some in another; but it was hardly possible they could all exist in any one shop. He did not believe that the workshops in this country were in such a miserable condition as the author would have us believe. Judging from the workshops he himself had visited in the neighbourhood of the Clyde, he would say that many of the modern machine methods advocated by the author were in use; and if the author believed that the workshops were in the condition indicated by him, then there was an enormous outlet and an enormous work for tool-makers to do. He congratulated the author on his Paper, and recommended every employer to study it carefully. The condition of our own workshops (according to the author) were laid painfully bare; he had skilfully advocated modern machine methods, and if the methods suggested, or even some of them, were adopted where they had not been in use, good results would follow.

Mr. **Daniel Adamson** said that another objection to milling the edges of plates in stacks was that most of the plates had to have bevelled edges, which did not lend itself to working in stacks. The author mentioned as a fact that grinding for cheap and accurate production was only a development of the past few years, but he had overlooked the Lancashire textile machine makers. A few days ago he was in a works engaged in that class of work speaking to men who had been in the trade for from forty to sixty years, and they did not know of any other system of producing spindles for cotton machinery than by grinding. The spindles were taken from the black forging and ground. He exhibited a spindle, and said that, although the makers had tried emery wheels for grinding these, they found grindstones more satisfactory. Emery wheels were used for pointing the end of the larger spindles, the machine being very similar in action to lathe centre grinding machines. The spindle-grinding machines could deal with spindles up to 44 inches long. The makers knew nothing about working to limits of 1–1000th of an inch in diameter, but they gave the speaker certain data from which he was able to find out that the limit allowed was 1–2000th of an inch, and as the portion of the spindle which had to be so accurately finished was taper, it made it more difficult to work to such a fine limit. It was necessary that the spindles should be accurately finished, because they had to be interchangeable and to be perfectly straight and balanced for running at high speeds. Spindles like the sample exhibited ran at from 8,000 to 10,000 revolutions per minute. Therefore any little irregularity in the assembling of the parts would prevent the spindle running satisfactorily. From 50,000 to 100,000 spindles were finished every week in Lancashire by grinding from the black forgings. The labour cost of the sample he showed was under 3*d.*, including forging, grinding, and straightening. Members who were at the Paris Meeting in 1889 would perhaps remember that at Decauville's Light Railway Works the tapering ends of the rails were being ground to form points and crossings in preference to planing, an example of rough grinding in use ten or twelve years ago.

The author spoke of turret lathes as though they were in course of development at the present time, but they had been used in the textile machinery works on a certain portion of the revolving spindle known as the flyer for at least twenty years, and for ten years turret machines of English manufacture had been used on work similar to a sample he exhibited which fitted on to the small taper spindle already shown. The labour cost on this did not exceed 1*d.* each. The makers were just commencing to make the same thing on automatic machines with magazine feed, but they were doubtful whether they would be able to make them as economically as with the hand-operated turret machine with one man to each machine—although with the automatic machines one man looked after six—on account of the smaller output per machine and the great initial outlay and greater wear and tear of the automatic machinery. The author mentioned that it was often a case of one man working three pieces in lathes versus three men working one piece in the forge,

(Mr. Daniel Adamson.)

and the speaker would like him to explain what class of work required three men in the smithy that could be done on automatic machines. General experience seemed to be that for the satisfactory working of automatic machines softer material was required than with the hand-operated or semi-automatic machines. Softer material lent itself to economical production, but it was not so suitable from the point of view of wear and tear, and to use hard material in the automatic machines reduced the rate of production so much as to render the machines impracticable. Another point not to be overlooked in working up pieces from the bar was the waste of material that took place. With suitable arrangements for forging, it paid to forge in Lancashire, even if only six per cent. of the material could be saved by so doing; and he thought the author ought to have made some allusion in the Paper to such economical methods of forging which had been used for at least the past fifty years in this country.

Discussion on 31*st January* 1902.

Mr. H. F. **Donaldson** said he had not expected to be called upon quite so early in the evening, but the author (who, he thought, was a man who, when he had made up his mind, generally obtained what he desired) had written to him asking him to speak on the subject, and therefore he had come more or less prepared to do so. The author had embarked upon a subject which represented a very wide sea, all the shores of which could not be thoroughly explored either in one meeting or two meetings, or even in a dozen meetings of the Institution. What the author had to say upon the subject had reference largely to the United States, with perhaps just a little of Germany; he had laid himself open to the charge of drawing conclusions and figures which would not bear very close examination, if they were to be used as true comparisons. Every one welcomed criticism, but the basis of that criticism should be solidly founded.

It did not do to bring any special pleading in the matter of figures, and to quote the worst time in some practice against the best time in another practice. It did not do, either, to quote any times without saying something about the material employed. Mr. Wicksteed had referred (page 48) to a particular instance of figures quoted for planing versus heavy milling. It seemed to Mr. Donaldson a very apt example to bring forward, especially with regard to those particular points which probably had struck several of the members.

Mr. Adamson had produced a specimen of grinding work done, as he said (page 56), by ordinary grindstones, work which had been carried on for many years and with great accuracy; but he (Mr. Donaldson) did not think that the author or anybody else was going to claim that grinding was a new thing. Mr. Adamson, if he recollected what he said rightly, informed his audience that when he asked the men engaged upon the work what limits they were working to, he gathered that they did not know anything about 1,000ths of an inch. It seemed to the speaker that that was a point which the author brought clearly before the Institution as a point which the members would do well to take heed to. The work of grinding those particular spindles could be more expeditiously and economically carried out, and at least quite as accurately, if high and low limit-gauges were used. That could not be gainsaid, especially by those who had tried working to a high and low limit, instead of with a pair of calipers or simple gauges. Personally he could say nothing with regard to heavy grinding, because up to the present he had had no practical experience of it beyond a small trial in endeavouring to prove the suitability or otherwise of a more extended trial. In the Paper (pages 25, 38 and 39) there were references made to the softness of metal. Looking at some of the machines from the United States and at the practical experience gained from their use, he thought it was one of the dangers of American machinery that ease of working in manufacture, sometimes to a most undue extent, sacrificed the life of the machine for which the material was to be used. He mentioned a case of practical experience where a machine had been at work only for a few months, and its screw already

(Mr. H. F. Donaldson.)

showed very serious signs of undue wear. That was not due to want of care, but to the softness of the material of which that particular screw was made. He therefore thought that any recommendation which the Paper might contain, to reduce the quality of metal used in order to obtain easier working, was open to grave dangers.

The author also referred to the laying out of shops, and gave a summary of the latest practice in connection with lathe work, which if adopted would necessitate a very considerable re-organisation, if not an actual re-building of the whole of the factory. Several new departments were recommended for introduction. In most works in this country, and probably in all countries, it would be found very difficult in existing works to sandwich a new system of working in the middle of an old shop. If it were possible to lay out works anew, there were many things manufacturers would be most happy to adopt; but with an existing equipment, if there was a small gain on paper to be obtained by a re-arrangement, it would want very careful looking at to see if it would pay to pull down workshops and build new, in order to introduce new systems. It appeared to him to be a question of pounds, shillings, and pence, taking it on the broad principle; and it was often desirable to have ocular demonstration that there was a saving, before it was possible to embark on a very large outlay. On page 28 there was a rather important word left out. In speaking of the question of cut gears, he understood the author meant accurate cut gear. There were quantities of gears on the market which were by no means accurate, and which were no better, and in many cases worse, than the old cast teeth.

The introduction into shops in this country of tool-rooms was a thing to be highly commended, and a greater extension of that was most desirable. The old grindstones should be eliminated from the workshop floor, and the workmen should be supplied with tools that could be depended upon, which should be always ready for them. An expensive workman engaged upon accurate work should not have to go away to grind tools. That could and should be done for him, and experience showed that after a few months he would get to appreciate the fact of always having a tool ready to his hand. With regard to making tools, there was a point about which he was not at all clear as to the author's meaning. The author said (page 37): "Those who proceed on this plan"—that was, making their own tools in their own tool rooms—"are liable to be constantly behind in respect to the latest designs of tools, for the reason that they come so little in contact with those who make a special study of tools and the best ways of producing them." If a workshop had a properly equipped tool room, he himself could not but think that they would be as competent to make tools of all shapes, sizes, dimensions and kinds as their productions required; and, except possibly for gauges which were special, the tools were generally speaking best made by the authority under whom they had to be worked.

On pages 41 to 43 there were eight maxims, all of which were good. There was, however, one point upon which he was not quite in agreement with the author, who practically grouped his machines of like nature together, and transported his work from place to place and shop to shop, following his chucking machine or his lathes or milling machines, or whatever it might be. Each of those operations necessitated transportation of the article being worked upon. That might do very well for some class of work, but he could not agree to its being applied to all classes of work. In most cases he favoured the least transportation possible. It might be slightly more expensive in the first cost of equipment, as it meant a few additional machines perhaps, but his view of an arrangement of a shop was that the work should follow a definite route, always passing forward, never crossing in its own track, and that the machines to enable that to be done should be placed in order to meet the sequence of operations aimed at. Of course he was speaking of a specialised shop.

With regard to the education of apprentices and of the grown-up workmen, so far as the education of the apprentice was concerned, the principle which seemed to underlie the author's recommendation was the return to the old apprenticeship of a hundred or more years ago, when young fellows were taken as apprentices and bound under penalty for a period of time. They were personally taught—that was the point he wanted to make—

(Mr. H. F. Donaldson.)

they were personally taught by those to whom they were apprenticed. Those who had anything to do with the employment of labour owed a duty to their successors, that they should at least improve upon the technical or working education of the apprentices, so as to bring them more up to date, in the same way as some were endeavouring to what was called modernise their shops. Both the education of the apprentice and the education to new methods of grown men were very desirable, and all that was possible should be done to help them forward for the good of the men, for the good of the employers, and for the good of the trade of the country.

Mr. John I. Thornycroft, Member of Council, thought the last point Mr. Donaldson had mentioned was the most important one, and, together with the improvement of the shops and the proper arrangement and collecting of tools most suitable for each particular purpose, deserved very careful attention. As had been pointed out by Mr. Donaldson, the tools must be the right tools and in the right order so that the work went through the shop as directly as possible. Unfortunately, engineers were frequently called on to do things that were very different, and what was in their shops varied so much, that not only the shops varied greatly, but the work in any one particular shop at different times. In a factory like the Royal Arsenal or Enfield, the work was of a more constant nature, and permitted of exactness and the use of limit gauges more conveniently than was the case with general work. He believed the Paper was one that called for admiration and consideration in every way, and thought it was a fact that the method of limits was applicable to a smaller number of articles than was previously supposed.

Lieut.-Colonel R. E. Crompton, C.B., said that he was much interested in the Paper, as he was one of those who had a modern shop, having been able to rebuild his old works on modern lines, after the fire which took place nine years ago. Since then he had recently completed another shop on still further improved lines, but before doing this he had spent much time in seeing the best works, not only in England but in foreign countries. He agreed in the main with the author's ideas. He had come to the meeting generally to hear what objections would be raised by English engineers to the general points of the Paper. He considered the author had made very few mistakes. He agreed with him on the limit gauge question, which made it much more easy to produce accurate and interchangeable work than the old but more expensive system of working to single accurate gauges. This older system depended for its success on the skill of the workmen. Working to limit gauges was one of the steps which engineers were taking to reduce the number of fitters, and to reduce the cost of erection. It was only where limit gauges were used throughout that this ideal was reached. It was curious that the Birmingham district, which used to have the name for turning out large quantities of goods, not of specially accurate workmanship, now had within the district several of the best organized shops for turning out thoroughly interchangeable work, and where the limit gauge system, worked by a well organized viewing department, was to be found in its most complete form. The full advantages of the limit gauge system could not be reaped until a viewing department was organized, not consisting of a few inspectors but with a full staff of manager, foremen, under-foremen down to the women and boys, who actually handled the material and used the limit gauges.

Turning now to the question of tool rooms. He had never been without a tool room, and therefore found it difficult to understand how a shop could be run without one. He could not agree with the remarks of the last speaker, that the proper use of the tool room was to make tools of all classes. He considered rather that its correct use was to keep existing tools in order, to serve them out to the workmen, receive them back, and put them into thoroughly accurate order before serving them out to another workman. The only tools which ought to be manufactured in a tool room were the jigs and templates, which were tools peculiar to the special business of the firm. Sometimes, no doubt in urgent cases, it was advisable to make a few milling cutters, drifts, and reamers, but generally these could be bought better and cheaper from firms who made a speciality of making them.

(Lt.-Col. R. E. Crompton, C.B.)

Referring to the author's remarks on the use of portable machines, he, as an electrical manufacturing engineer might supplement it by pointing out that the peculiarity of modern large dynamo machines was the great amount of time that must be spent on the armatures, which were pieces of circular work, sometimes as large as 20 feet in diameter, and worth when finished £3,000 or £4,000. Much of this large cost was due to the amount of labour which had to be expended on the armature, much of this again having to be done by machine tools. It could be readily understood that so long as the armature itself had to be worked at in the old style of lathe, only a few men could be got to work on it at a time. The hub had to be prepared in one lathe, then the arms got into position, with a possible return a second time to the same or another large lathe, then the core plates were put on and the slots trued out, and then it had to go into another tool to have the windings put on. This transfer from tool to tool, all of them of large size, made not only the labour itself, but the upkeep of the plant which had to be employed excessively costly. The most improved modern practice adopted by American, German, Swiss, and English engineers was to up-end the shaft on a planed surface table forming part of the shop floor, and then to carry on a number of operations simultaneously around it, by bringing up tools by means of the overhead traveller and setting them to work round the armature. None of these portable tools were of very large size, and it could be readily seen that the total capital value of tools employed by this method could be greatly reduced, and the total time taken in the shops reduced to one-fourth of the old figure. No doubt this principle of using portable tools could be used in many other pieces of machinery, on which large tool work had to be carried out.

The author did not say much as to the lighting of modern shops. He personally felt very strongly on this point. He was convinced that no good work could be carried out in a shop which was not perfectly lighted, both by day and by night. He had paid particular attention to this subject himself, and he thought that in this one respect English shops were perhaps a little in advance of those of their foreign competitors. He personally thought that the shop with the weaving-shed roof, adopted from the textile factories, gave the most perfect form of lighting. A good deal depended on the proportion of the incline and vertical glazed-roof surfaces, but if this were properly carried out with a north light, there ought to be equal lighting all over the shops, both in summer and winter, and no shadows would be thrown. As an instance of how much depended on such equal lighting, the vertical spindle lathe, of which the author said so much in his Paper, could not be used to full advantage if side lighting were employed, for it would be readily seen that, with side lighting from windows in the wall, the shadows thrown prevented rapid and accurate chucking on the vertical spindle lathe almost as much as on the ordinary surfacing lathe, but with even shop lighting the vertical spindle lathe had great advantages in the speed of accurate chucking.

He agreed with the author that it was not necessary to wait until large quantities of standard work were required before introducing most of the improvements put forward in the Paper, as a very small number of repetitions were sufficient to make the improved system pay. Lastly he wished to point out that after all this question of whether the system paid or not was the crux of the matter. In his own, the electrical business, Germany had erected some of the largest and finest shops in the world; enormous capital had been spent on them. They were splendidly equipped with tools, their methods of manufacture were supposed to be, and were in many respects, as perfect as possible. Their system of taking out costs was good and correct, but still he had his doubts whether, in view of the ever-varying work that had to be carried out in electrical engineering, the capital expenditure which had been incurred was justifiable; in other words, he asked himself the question, had the German engineers ever fairly debited their costs with fair interest and maintenance charge on their gigantic plant? He believed that if this had been done as fully as it ought to have been, many German firms would have found that they were manufacturing at a loss. He went on to say that, after all, the main object of these modern methods and the capital expenditure they involved was that of reducing as far as possible the

(Lt.-Col. R. E. Crompton, C.B.)

number of highly trained workmen, that is, the fitters, from the modern mechanical engineering workshop. He did not say that the highly trained fitter was not a good workman, but his position in the future ought to be in the tool room rather than working on the goods themselves. For this purpose a limited number of workmen must go through the training once considered necessary for all fitters, and probably the masters should go through the same training themselves; but the work could be now done so much better and cheaper by a more profuse use of plant which would be worked by an intelligent labourer, but not by labour requiring the same length of training as a fitter did. He was attempting to carry this principle out in his own works, but of course he felt that he was a very long way off the needed perfection. He was one of those who believed in women's labour, and the women should be set to work on tools of the very highest class, and under such conditions he had seen work turned out in Birmingham which was second to none.

Mr. WILLIAM WEIR asked the indulgence of the members in saying a few words on the Paper as he was not a member of the Institution, and as he thought it might be looked upon as youthful temerity for him to address a meeting of this character. As, however, during the last three years he had had an opportunity of putting in force in a new engineering workshop a large number of methods advocated by the author, he believed a few words on the subject might be of interest. It appeared to him that the Paper had suffered a little in general value from its evident restriction to considerations of conditions applying chiefly to engineering works doing fairly light manufacturing work. He considered that in this country the owners and managers of shops of that nature were and had been for some time alive and very progressive; and the shops over which the cloud of conservatism had loomed most largely were those doing heavy and more general work. It should be always remembered that those shops formed probably the largest portion of the engineering trade of this country. It was a truism to say that the tendency was to specialise; but the general shop was, and he believed it still would be, the one which had done and would do the original pioneer work in new lines of progress. By progress he did not mean progress in methods, but progress in research, in design, and in invention; and he trusted that in specialising, and in the desire of of being up-to-date in ways of doing work, engineers would not allow those considerations to blind them to the necessity of always keeping in view improvements in the design of their manufactures. If the British engineers could hold the position they had held until now as the best designers and the best engineers, as distinguished from the best shop managers, and at the same time give more attention to their shop practice than they had done, there was no reason to fear for the future of the industry.

The modernising of an old establishment doing work of a heavy or general nature, the maximum rate of profit of which was comparatively small, was a matter which required the exercise of very great discretion, and in his opinion very much could be done without any very heavy capital expenditure. First he would say, let there be more light in the shops; and that could generally be obtained without more windows — by washing the present ones. Then, cleanliness and order, to secure which the main necessity was a good floor. Expenditure on that floor would pay an excellent dividend in any shop, as it was possible to secure transport of parts up to about two tons at a minimum cost by the use of flat-wheel bogies. His experience had always been that shop railways were only required for heavy work, and, with a good floor with flat-wheel trucks, it was possible to take work anywhere, which was not the case with the usual "industrial railways." Then, better organisation was required, and the introduction of a system of remunerating labour in a better manner, say a premium system. There was also necessary a reasonably accurate and simple cost system. Next, more and better small tools and suitable arrangements for keeping them in order was desirable. If cleanliness and order were introduced into a shop, it would secure a wonderful amount of floor space for a tool-room or tool-stores. In his opinion those four items were the essentials in modernising a shop, and that their introduction must precede in every case "modern machine methods." Their cost of installation was comparatively small, but they secured a far higher rate of interest on the expenditure than could be secured by putting in improved machines. It was his conviction that old shops which had those features, or where those features had been attended to, and shops in which a fair average excellence of machine tools existed, would be the shops which could be depended upon for a better return on their capital than new shops in which every known labour-saving appliance had been installed, and which on that account bore on their shoulders the burden of a very heavy capital. In those remarks regarding the modernising of an old shop, he had in his mind a certain machine shop on the Clyde, which in about three years had changed from the old and in many ways uneconomical shop into what was certainly now one of the best equipped and best organised marine engineering works in this country. Speaking of the new shop, he had in mind a comparatively new marine engineering works in America, built at a very heavy cost to save the largest possible proportion of wages to workmen. The American shop obtained 30 per cent. more for its marine engines than the shop on the Clyde; but it could not pay a dividend, and would not pay a dividend until its original capital had been halved; while the shop on the Clyde would, he believed, be always a good investment.

The author said (page 29): "the loss of time and the inconvenience suffered in many shops by the want of a vertical boring mill is considerable. In many respects this machine is nothing more than a surfacing and boring lathe stood on end." He would like his remarks on that subject to be taken as applying to machines taking work up to 50 inches in diameter only. Presuming the surfacing and boring lathe was fitted with a turret head—in fact it was as up-to-date a boring and facing lathe as the vertical machine was an up-to-date boring and facing mill—where was the gain with the vertical machine for chucking operations and facing? The one machine appeared to him to be in every way as good as the other. For purely facing operations or boring large diameters, such as cylinders having a bell mouth, the horizontal machine was handier to work, as, on account of the compound rest, the workman could use both his hands at one time, and watch his tools. In the case of the vertical machine he was compelled to stand back from his work, and could only use one screw at a time, and must then take the handle off and shift it on to the other screw. That appeared to be a defect inherent in the machine for general work. Reference had been made to the extra power with which heavy cuts were possible with the vertical boring mill. It appeared to him that the tendency in shop practice was or ought to be to secure castings or forgings which would not require heavy cuts; and, as a general rule, he found that Scotch built boring and facing lathes were made with superior power to take all reasonable cuts at a fair rate of speed. The author said (page 30), with regard to the vertical machine that: "inaccuracies do not occur on account of over-hang." That might be granted for a vertical machine; yet the most accurate machine-work on fairly heavy engine parts done in this country, or, in fact, in almost any country, was done on properly designed horizontal boring and facing lathes. He therefore could not see that for general work up to 50 inches diameter the vertical machine was able to do the work of two facing lathes, if those lathes were fitted with turrets. In manufacturing work with special tools, the tools could be fitted as satisfactorily and do their work quite as well on a horizontal machine as on a vertical machine.

Speaking with regard to particular labour-saving machines, it had always appeared extraordinary to him that the most valuable labour-saving machine which he had in the works with which he was associated, although it had been on the market for about sixteen years, had been only adopted by a comparatively few firms; and strangely enough its adoption had been almost nil in what were termed up-to-date shops. The machine he referred to was called on the Clyde the horizontal, drilling, tapping, and studding machine; and consisted roughly of a large bed-plate on which to carry the work, a vertical standard sliding on the bed, carrying on it a drilling saddle which could move up and down the standard. Those machines had been in use for many years now, and their value was very great. Take an awkward casting which required four settings, say, a pump end. In a pump end at the first setting it was necessary to drill, tap, insert, and trim thirty-two $\frac{3}{4}$-inch studs; on the next setting the workmen had to bore three 1-inch holes, and also drill, tap, and stud

(Mr. William Weir.)

eight $\frac{3}{4}$-inch holes; and at each of the next two settings he had to bore twelve $\frac{3}{4}$-inch holes. There were no jigs or fixtures, and the holes were all marked off. One man and one labourer did that work in $2\frac{3}{4}$ hours, including the procuring the studs from the store, setting up, changing, and delivering the casting with the nuts all in position on the stud. He had occasionally wondered why people could get on at all without that machine; and he was sure there was no shop in this country of any size in which it would not prove an invaluable labour-saving appliance. He could not say why it had not been adopted, except that it had not been advertised and put before people, and that it was not of Trans-atlantic origin.

In conclusion, he wished to say how much he had appreciated the Paper, which contained very little open to criticism. He was sorry, however, that the author had written the Paper, as with his experience he could have written a far better book on machine shop practice. The Paper was too much in too little. The object of his remarks had been to counsel moderation in modernity; secondly, to point out what improvements should precede modern methods; thirdly, to ask for the up-to-date boring and facing lathe more consideration before discarding its use; and lastly, to claim for a Scotch-built and designed machine-tool the property of being the biggest labour-saving device in any shop using the most excellent types of American or Continental labour-saving machine-tools.

Mr. J. R. RICHARDSON thanked the author very much for the great trouble he had taken in preparing so valuable a Paper. The President had expressed his opinion that it was a subject on which there might be a great diversity of ideas, and there was no doubt that that was so. Colonel Crompton had said that one of the reasons he had attended the meeting was to hear what English manufacturers had to say for themselves; he, the speaker, had come in defence of the English manufacturers. The Paper was really a severe criticism of English methods, comparing English methods most unfavourably with the methods in America. The English method appeared to be to have tools which would do anything they were wanted to do, but not doing the work so cheaply as it might be done; the American method was the system of having tools and plant so arranged that whatever was done was done in the cheapest possible way, the tool being of comparatively little use for anything but the one thing for which it was made. Of course this was putting the case very broadly indeed. The author stated (page 17) that the adoption of milling machines was not "as extensive as it should be, for the reason that often an apparently formidable investment in cutters is necessary. The milling cutter, however, should be looked upon as any other labour-saving tool. It is not so much a question of how much does it cost, as how much does it save." Further on in the Paper, the author said (page 44): "The idea that big quantities and standard work are necessary before modern equipment begins to play an important part in the economics of manufacturing is the delusion of those who have grasped but a small part of the problem." Mr. Richardson was afraid that he must rank himself among the deluded ones. Many years ago he introduced automatic and semi-automatic machinery for the manufacture of all small parts, such as pins, studs, small brass details, nuts, and things of that sort, used in very large quantities. They did not take up much room, and it was not a serious matter to hold a twelve months' stock. But in large engine details the question was rather different. There were very many engine details, where the work of the milling machine would be very much cheaper than by the old-fashioned slotting machine, as far as the question of wages was concerned. Was that the only thing to be considered? Some years ago when this country was flooded by gentlemen from the other side of the Atlantic, who were anxious to show English manufacturers how to manage their works and make large fortunes, and incidentally to buy American machinery to do it with, a gentleman called upon him with regard to milling machines. This gentleman said, "If you will allow me to walk through your shops I have not the slightest doubt that I can pick out a large number of pieces you are tooling, and show you how you can save 50 to 75 per cent." He was always very glad for anyone to show him anything like that, and gave the required permission. The gentleman went at once and found six or eight pieces which he took as samples, and

(Mr. J. R. Richardson.)

said he would give estimates for machines, cutters, and everything necessary for doing the work, and actually guaranteed the time for doing the work. The results all came out practically alike, and one illustration would suffice. He exhibited a template of a lever used in one class of engine. It was set out by the fitter, and slotted all over by hand. The slotter worked the machine round the curves following the fitters' marks. There was nothing automatic about it, and the total labour of slotting was about 1*s.* 7*d.*, the time being one hour and twenty minutes. The American's estimate for doing the work was 30 minutes, practically a clear saving of 66 per cent. That looked very nice on the face of it, but the machine to do the work was to cost about £250. Besides that, the American wanted to supply two sets of milling cutters at something like £30 a set. Only four of the levers were used on an engine, only one particular engine used them, and they were only good for one size; the result was that, although the turn-out of the whole works averaged three engines per day, the total saving upon these levers would be simply 13*s.* per annum.

Only a few weeks ago he had been approached by a gentleman introducing moulding machines, who showed him some fascinating photographs and drawings of what the machines were doing. To see a foundry floor covered over with hundreds of boxes, and to be told that one standard machine did them in a day was delightful. He said he did not think they could use ordinary patterns, and one of the visitors told him that they did. Mr. Richardson said he thought they had to be mounted in a certain way, and was told that they had to be put on plates, and a stripping plate had to be provided. He asked whether that was not a serious question with a large variety of patterns, and was told not, because there were always in every works a great number of patterns in regular use, apart from those only used occasionally. He took the party into the factory, and showed them the patterns, pointing out some 17,000 patterns in one store, and explaining that there were five other stores containing patterns not used so frequently; the American guessed that that machine was not exactly suitable for that class of work. It was not that English engineers did not understand American methods, but that Americans did not as a rule understand the conditions which obtained in large engineering works in England having a big general practice. There must be a large run of work. Even the most enthusiastic Americans had told him that a large quantity was not needed, that it could be done perfectly well with a dozen, but very often a dozen was a large quantity. Not only was it necessary to have on his catalogue 500 different types and sizes of steam-engines, but an infinite variety of mining and general machinery; and in addition his firm was expected to do anything required, and had to do it even if it only had to be done once. He did not wish anyone to gather that he was in the least degree opposed to modern methods; full, semi-automatic machines, turret lathes, vertical boring mills, flat, cylindrical grinders, hydraulic, pneumatic, and electrical power plants, and a testing and analysing laboratory had all been installed under his directions, and he thought that even the author would not take exception to the lighting and ventilation. Though up to the present his firm had not been fortunate enough to discover "foremen who were experts in turning, milling, grinding and planing, and who could do their own tool-making, inspecting, and cost-keeping at 50*s.* per week."

As far as his experience for several years in America went, he thought the Americans were deserving of the very greatest credit for the accuracy with which they turned out their work. Fire-arms, bicycles, sewing-machines, and things of that sort were turned out in very large numbers finished most beautifully without the use of the fitter. That was due to the accuracy of their jigs and limit gauges, and the excellent system in the works. In larger work, where hand-labour had to be used, very great accuracy was shown. Quite recently he was building a large engine, the shaft of which had to carry an American armature. The specification was American, and specified that the armature was to be forced upon the shaft by hydraulic pressure, not less than 50 tons nor exceeding 80. The armature came over to this country, and fitted dead true into its place with a pressure of 65 tons. That spoke very well for the accuracy with which that armature was bored in America, and it

(Mr. J. R. Richardson.)

also spoke equally well for the care with which the shaft was turned in England. Speaking of American specifications, he thought sometimes the Americans overdid them in their desire to appear extremely accurate. He remembered not very long ago it was specified that a certain key was to be driven home with a ten-pound hammer, but they neglected to name the length of the shaft, or the strength of the man who was to strike the blow. Some years' experience had shown him that even the very best known and largest American firms were not always so prompt in their deliveries nor so accurate in their construction as they would have English manufacturers believe. He had known works, not hole-and-corner works, which had exceeded their promised time of delivery by over twelve months, and when the machinery arrived and was put together discrepancies arose, discrepancies not of 1–10,000th part of an inch, about which they talked so glibly, but of a considerable proportion of a foot.

Mr. LEWIS H. RANSOME said he had not come to discuss whether English manufacturers were better than the Americans in the way they turned out their goods, as he thought the results would speak for themselves. He had come as a shop manager to ask a few questions on points that struck him as being of great interest in the Paper. The first, the question of limit gauges had been answered by Colonel Crompton, and it appeared to him that this system appealed to common sense. His firm had been hesitating for some time whether to adopt it or not, and if any member present had used limit gauges it would be interesting to know what his experience of them had been.

The chief thing that had struck him and filled him with a certain amount of disquietude was the speed with which the author said some of the machine tools could be worked. In many instances his firm had not attained such speeds as were mentioned in the Paper, but he was anxious and willing to learn; perhaps the author or some other member could enlighten him as to how such results were arrived at. With regard to circular milling, the author stated that it could be done on cast-iron with a cutter having a surface speed of 50 feet a minute and a feed of 4 inches a minute. That was much better than anything they could do in his works, and he did not mind admitting it. The average cutting-speed in their own shop was 35 feet a minute, and on cast-iron they could get up to a feed of $1\frac{3}{4}$ or 2 inches. That was the best speed at which they could turn out good work, and he thought it would be of great interest to most of the members to know how it was done in America, what quality of steel was used, and how it was tempered to turn work out at the rate spoken of. He wished also to know whether the author, in giving this rate of production, allowed for the five minutes extra in the machine shop for excellent finish, which would save ten minutes in the fitting shop spoken of later on in the Paper.

He was very much interested in the question as to the advisability of putting two or more speeds on the planing machines. That was a question his firm had not settled. When he was in America he saw a good many factories working with two speeds, but he could not get any definite information as to results. His firm were running their planing machines at a standard rate of about 18 to 20 feet a minute, and when planing wrought-iron he thought it would be better to drop to a speed of 15 feet. If any member present was running his planing machine at two different speeds, it would be very interesting to hear his experience of it. It seemed that with a standard speed, if a quicker output was desired, it could be got over to some extent by taking a coarser feed and a deeper cut, and in that connection he might mention that they had a large planing machine in their works to which a tool-holder had been fitted with four tools. With that tool a feed of a quarter of an inch could be taken, removing as much as half an inch in depth at one time with one cut. The only drawback was that occasionally, when the work sprang under the excessive pressure, it was necessary to take a second finishing cut. In finishing, a feed was taken about three quarters of an inch with a flat tool, and it paid better to run twice over the work with a finishing cut than to spend less time in roughing it out and finishing with one cut.

Another interesting feature in the Paper was the question of grinding. He had no hesitation in endorsing the author's view as to the economy effected by grinding in preference to finishing on small work. Since his firm had put in a universal grinder he reckoned they saved 25 to 30 per cent. of time, and got a much better finish. The time of the lathes was saved, the files saved, and the spoiling of the machine by the use of emery, and the work was done a great deal quicker. But his firm did not grind at anything like the speed the author mentioned in the Paper, although they would like very much to be able to do it. The author said that a shaft 4 inches in diameter and 3 feet long could be ground up, removing the hundredth part of an inch in six minutes. He was almost ashamed to say how long it took him to grind it compared with the figures given in the Paper. He did not doubt for a moment that the metal could be removed, but the thing was whether the shaft when finished at this speed could be run afterwards at a speed of 800 or 1,000 revolutions a minute, which was an average speed for their shafts to run at.

He was greatly interested in the tool-room question; and having lately started new works and beginning with a clean slate, it might not be waste of time to mention his firm's experience in this direction. In their old works at Chelsea there was no tool-room, and the new works were started without a tool-room, but provision was made for adding one afterwards. The first thing they did was to collect all the old tools about the shop, and they cleared up 3 tons 5 cwt. of useless tools. A considerable time was spent in doing these tools up and putting them in thorough order, with the result that they had not bought any tool steel to speak of for nearly twelve months. They then arranged a system of messengers for the tool-room, as no workman was allowed to go into the room for his tools. Messenger boys were provided, and there was a system of bells in every department. The bells had an indicator in the tool-room, and a blue print showing every standard tool was hung up by each bell. Every tool was numbered and described. The boy who took the order did not need to know what tool he was bringing, because it was kept in a bin with a standard number over it. The workman rang the bell, and when the boy answered it, he asked for tool number so and so. The result was, he estimated, that five men's time was saved. He used to total up the number of men he saw hanging about the tool-room previous to this system, and generally there were five to six all day long. Now boys were employed at 4*s.* and 5*s.* a week running about the shop in the place of men getting 36*s.* to 38*s.* He was not ashamed to say the idea was obtained from America, but it had been developed.

There was one other point in connection with foundry practice, and that was the necessity of having someone who could analyse cast-iron and coke. In a foundry of moderate size it was not perhaps possible to afford a chemist; he did not know what a good chemist would cost. His firm was absolutely in the dark, until it made the castings, as to whether the brands ordered contained the same component parts as similar brands ordered previously. As a matter of fact he knew that they did not. Then it was not known what the coke was. Only a fortnight ago, tempted by a lower price for coke, his firm purchased some, with very disastrous results. If someone had been on the spot who could have analysed that coke it would have paid well, and he had been wondering whether it would not pay for neighbouring foundries who were not large enough to keep their own chemist to combine and run a chemist between them. There was one thing he wished to touch on in conclusion which did not refer to the particular Paper under discussion, but to papers in general. The manufacturers in this country were a great deal too thin skinned. Judging by the discussions he had attended or read, the papers on improved methods of manufacture were read by British manufacturers very much from a defensive point of view. He maintained that this was a mistake. What was wanted to be obtained from these Papers was information. Manufacturers did not want to get up and prove that they were cleverer than anybody else, or to tell the author their own methods were better than others they were not familiar with. Results would prove this. They did not want to tell him, if he stated that he could do work quicker than the English manufacturers, politely, but unmistakably, that he was a romancer. They wanted to discuss and find out if his statements were borne out by facts, and if they were, manufacturers should learn from them. If they were not, then there was no harm

(Mr. Lewis H. Ransome.)

done. No doubt manufacturers had learned a great deal lately from America and the Continent. English manufacturers had been ahead for a great many years, and he believed and trusted they would maintain their position, but they would not do it by shutting their eyes to what was going on outside this country.

Mr. **Robert Bruce** said he appreciated the Paper, which was the product of the author's experience in workshop management, both in America and Europe. They in England should be glad to profit by such experience and suggestions as were conveyed in the Paper, for though engineering had sprung up in this country and had practically led the world, there was certainly no monopoly of engineering talent in this country.

The author had laid before the Institution much very practical information and suggestive matter, which would not be lost upon that section of the membership directly engaged in workshop management. Already in many workshops in this country the views and methods embodied in the Paper had been adopted to a large extent with gratifying results, and doubtless, as it became widely read and understood, its influence would be felt amongst users of machine tools.

Mr. **David Carnegie**, speaking of limit gauges, thought it was generally understood that the principal advantage was in being able to use the gauges with practically unskilled labour. He quite agreed with Mr. Ransome that, where the limits amounted to five-thousandths of an inch, unskilled labour could use the gauges successfully. Gauges to much finer limits, as described in the Paper, could also be advantageously used by mechanics. It was, however, necessary to couple with the use of limit gauges that of an inspection branch. In having the work inspected limit gauges could be used, and it had been found from many years' experience that interchangeable parts could be made successfully in that way.

With regard to milling tools, he had found that a great saving was effected by the use of milling machines for producing tools, say cutter-bar tools. They could be moulded to shape and hardened without going near the fitter, and work could be produced by such cutters which could be gauged within reasonable limits. With reference to the tool room, no workshop could be looked upon as fully equipped, unless the tool room was under proper guidance. Someone had said that the tool room should exist mainly for storing tools, or that only small tools should be made there. It was necessary to distinguish, he thought, between a tool room and a tool store. The tool store was simply a place from which various tools could be issued to messengers or operators. All tools as far as possible should be made in the tool room. A system had been successfully carried on for two years, where tools had been ground by universal grinders, and handed out properly ground to the required angles for the various materials, and thus a great saving was effected by the use of the tool room or store in that way.

Mr. ALFRED J. HILL, in answer to Mr. Ransome's question (page 75) as to the advantage of two speeds for planing machines, said he had recently adopted two speeds to all his planing machines with very good results. He thought the speeds Mr. Ransome mentioned for cutting wrought-iron were very low indeed. For cutting cast-steel, his firm were running their planing machines at about 18 feet a minute, and for cast-iron and wrought-iron 27 feet a minute. He thanked the author for his Paper, which he thought fulfilled the chief aim the author had in view, that of suggestion to those who were considering economical methods of manufacture. He thought, however, the author had gone in rather for a counsel of perfection. As a manager of shops he should be only too glad to follow in many respects the lines indicated in the Paper, and would like to know whether the author knew of a shop in this country where one man was working six milling machines. With regard to grinding, it was recorded that a 4-inch shaft 3 feet long could be finished on a grinding machine in six minutes. There was a specimen, Fig. 31, Plate 8, somewhere about this size, though certainly rather larger, but it had been ground in forty-five minutes, and he thought that sounded a more reasonable and practicable time than the six minutes mentioned in the Paper.

Mr. ROBERT DUMAS said he was lately in the States where he saw some planing machines fitted with the Reeves variable speed countershaft, and planing was being done on cast-iron at the rate of 38 feet a minute. He would not mention the place where he saw it, as the article being planed was the standard of a milling machine, and it might not be thought altogether a recommendation that it was possible to plane cast-iron for that purpose at that speed. As to whether in this country there were six milling machines worked by one man, he could assure the members that there such was the case, but he would not mention the name of the factory for very obvious reasons.

Discussion on 21*st February* 1902.

Mr. E. J. CHAMBERS could not help saying how very pleased he was when he read the Paper. He had not had the pleasure of attending the previous meetings, and was very disappointed that he could not come; he thought, however, that the author was working on the right lines. Although he could not subscribe his name to everything the author advanced, he still felt that it was the kind of Paper necessary to be brought before the Institution. With regard to the care necessary when one began to dogmatise as to which machine in a shop was best, he remembered some years ago making a machine to do a certain work. He went on with the work and developed it, and as soon as he got one machine to work he started another, and he thought he was going on splendidly. The machines did their work very well indeed, and he thought he would be able to carry all before him. But unfortunately in one of his weak moments he started scheming another way of doing it. The first method was in the turning shop, the second in the smith's shop. Most works had a smith's shop, a foundry, and a turnery, and various other shops, and unless a manager gave each shop a look in, it was not quite fair to the works generally. He happened to start scheming in the smith's shop, and found it was wonderful what the smith could do by simply sticking to it. After having spent several hundred pounds in designing lathes to do a certain particular work, he found not only that he could do that work under the hammer in the smith's shop very much better, but also very much cheaper. Consequently one had to remember that there were other departments which could produce work to a wonderful degree of perfection, and that work could be well done even in the smith's shop by only devoting attention to it, work which would knock the bottom out of any suggestion for cutting metals off by a lathe. He remembered one gentleman he was associated with many years ago, who said it was always cheaper to cut metal off with a lathe than it was to go to the trouble of making dies, and forging it under the steam-hammer or in special stamping dies. It struck him at the time that it was perfectly true, but both of them lived to see that by developing knowledge and experience of dies and stamping they could beat the lathes, and that they could not always cut the material off as well or as cheaply as it could be done in the smith's shop. Therefore they had to go back to the smith's shop again. It was that which he wished to caution the author about. Although he liked his advice very much, he still felt that it had to be qualified, by remembering that when one shop had been beaten, that shop must be called upon to beat back, and that was the only way to get perfection.

Mr. F. G. Wright said he had taken great interest in the Paper, and he wished to ask the author one or two questions on the subject of apprenticeship. He assumed that the author's remarks referred to shop apprentices, that is, youths apprenticed with the idea of becoming fitters, turners, or erecters, and continuing at these trades. He wished to know whether the author proposed that, in addition to these apprentices, youths should be apprenticed to the working of milling, planing, drilling, and other machines, and should be kept entirely upon such work.

The President said the Institution had received from Mr. Dean a written communication containing interesting data as to the extent to which grinding was being done at Swindon, and he asked Mr. Wright whether he could tell the Meeting anything about the practice there?

Mr. Wright said that at the present time in the locomotive works there was grinding machinery for finishing off rough forgings, and special machinery for grinding piston-rods, valve spindles, solid spindles, and so on. He did not know that there was anything different from what other large locomotive manufacturers had at the present time.

Mr. T. Hurry Riches, Vice-President, said that Mr. Wright was aware that his—the Taff Vale Railway—Company had some grinding machinery, and they had found a very material saving in a great deal of the work in consequence. So far as repairs were concerned, at one time they turned down old piston-rods, but they did not dream of doing that now. The piston-rods were put in the grinding machines and brought to a very fine surface indeed. Metallic packing was used, and it was quite a common occurrence to run engines two years on the line without requiring to touch them. In addition, with regard to the whole of the motion, whether holes or pins, the old practice was to soften and in many instances to close more or less oval holes, and then having drilled them or bored them, harden them again, and then lap them out; but that practice had been given up for a long time. Now the case-hardened rod or pin, as the case might be, was taken and put into the grinding machine, cut up, and the job made as near perfect as possible. There again it was found that the saving in the fitting up of a motion was very material indeed. Further than that, the whole of the new piston-rods were finished with a grinding machine, instead of as in the old days finished in a lathe. The whole of that work, whether new or old, was dealt with entirely by grinding machines. All the rough steel castings were ground, either with stone grinding, corundum, or emery machines or wheels. The only thing to take care about was when the grinding was finished to clean the hole or the pin just a little, just enough to wipe the emery or corundum off which might be left by the machine. It would be found that the cost of repairs or the cost of making new work was distinctly decreased.

He quite agreed with Mr. Chambers that the method of machine shop work and management now required very careful watching.

Having set one's self to perfect one shop, as soon as it was considered that that was right, then a good works-manager ought to begin on the next shop, and see if he could not make it better. He was quite satisfied, he might fairly say, that he had some of the best American and modern machines in the Taff Vale Railway shops of any shops in England, although they were only small shops. He could say very positively that there was a great deal of work which professedly was done cheaper by turning—for instance, cutting bolts out of solid bars or cutting other things out of solid bars—which could be in many instances much better done in the smith shop, particularly where there was a large amount of duplicate work. Stamping, if properly done, could enormously decrease the cost of manufacture; and so it was from shop to shop. Taking the boiler shop for instance, drilling, reaming, caulking or chipping required really constantly revising. If they were to go from one point to the other to improve one shop and then another, and then bring the other shop up to that, there was a constant and steady process of improvement and development. In his opinion that was the only way to keep ahead or on a level with other nations, and in fact, as Mr. Chambers said, to keep pre-eminent. As soon as one shop was ahead of the others, the others should be brought up to it. He had been asked by the President whether he ground to new standards. The new standards for motion pins and holes naturally would be smaller than the repair standards. But it was found very much better to slightly increase the standard for repair work, as compared with new work, than it was to bring the old work down to the standard of the new work. It was very much better to have a second standard a little larger that would take the work through.

Mr. Orcutt, in reply, said he first of all wished to clear away a personal matter raised in the discussion by those who criticised the Paper. He believed his countrymen had one failing, that they were never able to disguise themselves, and he was suffering from that. He was sorry, not that he should like to try to conceal his identity, but he thought little would be gained by making the *national* question one of prominence. Those who had

(Mr. Orcutt.)

criticised the Paper most sharply had assumed somewhat, and stated rather plainly he thought, that the Paper tended to be a eulogy on American methods and an indictment of English workshops. That was far from his object, and nothing whatever was gained by it. The object of the Paper was to present what he considered to be the best practice, in many cases extreme practice. The Americans had a very good motto, which said "Aim at the stars, though you stick in the mud"; and he thought that manufacturers should always work in this spirit. Naturally in dealing with the matter he had American leanings, as he had had a large experience in American shops as well as in English and German shops; but at present he was domiciled in England, all his friends were in England, and his home was in England, and he had the interests of the English shops and industries at heart. He thought some of the members would testify that the interest he had in industrial progress in England was in no way connected with selling machinery. One thing he had learned in a long residence of thirteen years in England was the labour-saving virtues of plain speech. He had tried to use plain speaking in the Paper, and he proposed to use it in the reply. After he had gone over the points which had been brought up by those who took part in the discussion, he proposed to say briefly and exactly what he thought of English workshops.

In the first place Mr. Wicksteed brought up the question of milling (page 48), and seemed to assume that the example brought forward of milling lathe-beds would not apply to flat milling; but it seemed to Mr. Orcutt that that was a question which must be always studied. It might be true in some cases, and it might not in others, that milling would be better than planing. If he were attempting to finish English lathe-beds quickly and cheaply in quantities, he would resort to vertical milling with large milling cutters with inserted teeth, and he thought nothing could beat it. In his own shops screw machine beds were milled which had a flat top section. They never went to the planer at all; they went direct from the miller to the scraper, and only two cuts were made. With regard to a large cutter on a broad surface springing, it certainly would spring if the machine was not adequate to take the strain, and so it would in the planing or any other machine not sufficiently rigid. A great trouble with milling was that in many cases the machines were not powerful enough. Machines were used of slight construction, and then condemned when they had not had a fair trial. Mr. Wicksteed also thought that three cuts might be necessary to finish a lathe-bed. He never made three cuts; it was not found necessary. There was one roughing cut on the milling machine, and one finishing cut on the planing machine to bring it true, and then it went directly to the scraping machine. Mr. Wicksteed very rightly brought up the question as to the milling machine superseding the planing. This was not yet accomplished, although many predicted it; and it never would be so. Both types of machine must be used, and always would be used. He thought members should make use of the figures (page 49) given by Mr. Wicksteed, which were valuable as showing the speed at which planing could be done, particularly with the cutting on both strokes.

Next came Mr. Rowan (page 52), who also criticised statements as to milling-machine work, and wrongly, because Mr. Rowan was probably thinking of large work, whereas the Paper, while dealing with that, was principally devoted to light milling, and the instances mentioned in the Paper were very largely in connection with that class of work. Mr. Rowan questioned that milling machines worked two or three times faster than planers, and said that such cases must be exceptional. There was no question whatever, as many of the members could testify, that in a great many cases where it was applicable, it beat the shaper three or four times, particularly as to labour cost. One man could very often easily attend four milling machines, while it was not usual for one operative to attend as many planing machines. Mr. Rowan also thought that the planer was not such a long-suffering machine as had been assumed, but the author would like to have the privilege of taking him into some works into which he had been, when he thought he would change his mind a little in that matter. The cases of course could not be mentioned and no names could be given, but they could be easily verified, and they occurred over and over again. Mr. Rowan very rightly made the point that the cost of a piece of work did not depend upon the

(Mr. Orcutt.)

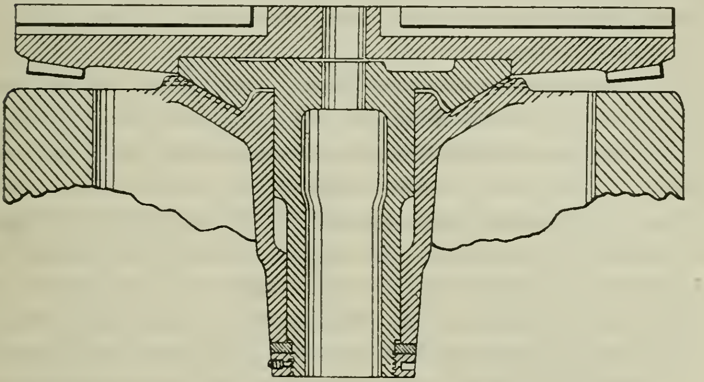
speed at which it was cut entirely; there was the depth of the cut and so forth. Of course in the output the quality of the iron very largely regulated the speed at which the work could be done. Feeds, speeds, and depth of cuts certainly regulated the output, but work at fast cutting speed would make it possible to increase all round.

Mr. Rowan brought up another very good point in respect to cost-keeping (page 53). He, himself, thought the value of accurate cost-keeping was not understood as much as it ought to be, and that cost-keeping was not carried out as it should be. If it was done properly, there were some revelations in store for some manufacturers. Mr. Rowan was specially informed in connection with that matter, and anyone interested particularly in the question should see his works, which he always threw open to those interested. Again, Mr. Rowan spoke of the vertical boring machine as compared with the face plate lathe (page 52), and did not see the advantages of the former. That question was almost as eternal as the flat-bed lathe versus the V bed, but there were points in favour of both machines. When Mr. Rowan made the statement that no engineer would credit that the boring mill did double the work of the face lathe, he (Mr. Orcutt) thought he could bring forward any number who would testify that it did. In some classes of work it was especially applicable. Fig. 35 (page 87) illustrated one of the points, and to that drawing he called attention. It showed what was usual in some constructions of the vertical-boring machine, as made by one of the leading makers. It represented the face plate of the machine and the conical bearing on which the main weight of the spindle and face plate was taken. He thought it only needed common sense to see that it had features which it was impossible to embody in the lathe for certain classes of work, particularly where heavy parts were to be operated upon. The construction as shown had a self-centering tendency, so that the combined weight of table and spindle, as well as the work, tended to preserve, not to destroy, alignment. In fact, it was impossible to get results on the lathe which could be obtained on the vertical boring mill for that very reason.

Mr. Rowan very rightly warned the members to be careful in making too elaborate shop fittings and so forth; making the shops too nice and comfortable. He did not know whether Mr. Rowan was fishing for a compliment or not, for if he was, he deserved it, and he proposed to give it to him. Mr. Rowan had one of the finest shops in the kingdom; he had a very fine fitted engine room; shops laid out with splendid floors—clean orderly shops; fine tool stores and factory fittings. In fact, from Mr. Rowan's warnings and criticisms he rather thought he had a good thing, and would not mind throwing his competitors off the scent. Speaking of that question, which was certainly important, and one in which all mechanical engineers were interested, one was always met with the statement that it did not pay. It was a large question. But the thing was, whether a man wanted to fit up his shops better or not, he would have to do so before long. Conditions were changing. The engineering business was not the dirty trade it was thought to be by some. To his mind it was one of the highest professions to which men could apply themselves. It must not be forgotten that good shops, good surroundings, good fittings, comfortable clean places, helped to retain a good class of employees, a matter with which there was always some difficulty. If good men were to be retained, they must be given good salaries. The standard of living was increasing, the workmen demanded much more than they did

FIG. 35.

Boring and Turning Mill Table, with Conical Bearing. (Bullard.)



(Mr. Orcutt.)

even ten years ago. They must have better surroundings, better pay, and better facilities. Education was creeping in, giving the workmen new ideas—and very rightly, because it was progress. Wages were increasing. The purchasing power of money was increasing. All those things pointed to the necessity, whether a man would or would not, of making shops better. He thought it would pay very well to consider the question. Another point was with regard to the heating of the shops, and keeping the tools and machines in good condition. He hardly thought it could be proved, but some cases were very glaring in the impossibility of keeping plant in good condition, on account of moisture, which rusted and destroyed everything. Another advantage in having up-to-date shops was that it put one in a better position to deal with business, both in good and bad times.

Mr. Rowan made a statement that he could not understand how one foreman could take charge of 40 to 50 men, and the author thought that occurred owing to his looking at the matter from too narrow a standpoint. It was very easy for one foreman to take charge of 40 men in a light manufactory and very often even more, but perhaps 50 was about the limit. Mr. Rowan was rather indignant to think that a foreman worked for 50*s*. a week. He himself was very pleased by that, because he thought it was a hopeful sign. He wished Mr. Rowan's indignation would extend to every member of the Institution and every shop in the land, until such a thing as a 50*s*. foreman did not exist. He must say though that it was not a fact. He knew, and many of the members would confirm it, that it was the deliberate policy of many manufacturers and employers not to pay more than 45*s*. He had confirmed that by enquiries of large manufacturers. He did not approve of it. If it was done, he thought it would be soon learnt that it was not the most economical way of managing. Mr. Rowan further made a false assumption from a statement in the Paper. He assumed that the author had said that Americans were not in the same street with this country (page 43). The quotation from the Paper was as follows: "There is a widely spread and erroneous idea, particularly amongst European manufacturers who would emulate American manufacturers, that the latest methods cannot be economically adopted except where work is thoroughly standardized, specialised, and made in large quantities." That was mentioned not to show the superiority of anybody, but simply to bring out an idea with which he came in contact constantly when dealing with manufacturers. He was met with the statement again and again that new methods, modern methods, could not be adopted—many of which were adopted in America—except the full American idea was adopted of manufacturing enormous quantities, putting down special plant, and standardizing everything. The statement suffered from brevity like a good many others in the Paper, but the idea was to show that that was not the fact. Many labour-saving appliances could be adopted without changing the product of the shop in any way whatever, and many instances could be brought up to show that. For instance, it was easier and cheaper to finish cylindrical parts by grinding than by turning them. How many shops had grinding machines? It was far better and cheaper to bore holes with a good chucking outfit; yet how many shops had that department? It was far easier to turn the work to limit gauges than standard gauges, and yet how many shops adopted that? It had nothing whatever to do with standardizing or special output. His idea in making the statement was to bring that fact home. He had seen many cases, and he thought one was worth citing without mentioning names. He was recently in a shop where they were turning a very large shaft with a great many different diameters on it, and he said he thought the work could be done much easier and much more cheaply by using limit gauges than by carrying a piece sometimes weighing 200 lbs. and fitting the shaft into it. "Well," said the gentleman, "look at the number of diameters on this shaft—how many gauges should I have to have?" The author said, "You had better go to your drawing-office and reduce the number of diameters and then you can adopt gauges easily." There was nothing radical about it; it was simply common sense.

Mr. Rowan further stated that he thought the apprenticeship arrangement as far as engineering was concerned in this country was very good, and did not agree with what was stated in the Paper.

(Mr. Orcutt.)

Again, he thought Mr. Rowan had in mind heavy work, where the apprenticeship question was not felt perhaps as acutely as in the light manufacturing where labour-saving machines were more largely adopted. Manufacturers all over the country were feeling the question very much, the difficulty of securing intelligent progressive workmen in their shops, and he was sure it went back very largely to the apprenticeship question. In doing heavy work where it was simply a matter of a forge tool and a heavy machine, he thought the apprenticeship question did not call for changes as much as it did where fine tool work was depended upon. Experience showed that there was a very wide-spread interest in the matter. He asked Mr. Rowan how many apprentices were trained in the thorough understanding of turret machine work, cutters, milling work and grinding work? How many were thoroughly acquainted with proper boring and chucking systems? How many had an opportunity of practising on jig work; how many went into the tool room to work? All those questions affected labour-saving machinery, especially in work of a light kind, and he thought apprenticeship methods were sadly wanting in giving training on thorough modern lines. He desired to call the members' attention to an Address * which had been just delivered in Manchester by Mr. E. G. Constantine, in which he made very strong statements.

Mr. Rowan stated that his, Mr. Orcutt's, Paper implied an absolute want of knowledge of machine methods in this country and complete confidence in America. He hardly thought that was a compliment. The inference was entirely wrong, and would not bear the slightest investigation. There were many good shops in England, and many bad shops in America. He had taken the best he could from each. One point he thought the members would agree with him was that very few shop managers were acquainted with all the latest shop methods and arrangements. He found that shop managers were as a rule men who rode hobbies, and did not get outside of them enough to attack the question generally. As several of the speakers had shown, it was a very

---

* Transactions, Manchester Association of Engineers, January 1902.

wide question and an endless one. He wished shop managers could get away from their narrow lines.

Mr. Adamson (page 56) thought the Paper had overlooked the spindle grinding in textile machine work, and he showed a sample of spindle grinding which in itself was a wonderful piece of work, but was hardly relevant to the subject in hand. It was a sample of ancient rather than modern work, having been done on the grindstone by hand instead of on a grinding machine with limit gauges. As Mr. Adamson had testified, they did not know the limits they were working to; they had been making the things for years, and the great skill they had acquired enabled them to turn them out accurately without any modern plant. He was thoroughly acquainted with that work, and considered it a wonderful operation, showing what the skilled hand could do. Like other operations grinding was not new. It was one of the oldest of all. To bring forward that sample, however, was hardly to the point. Mr. Adamson further mentioned turret lathes, and seemed to imply that the Paper overlooked that lathe in the textile industries, particularly in the Manchester district. Mr. Adamson said he had seen turret lathes which had been in use for twenty years. He thought he could show Mr. Adamson some that had been in use for fifty years or even more by the look of them; but they were not modern turret lathes. Tho turret lathe was not new, any more than the grinding machine. But the modern turret lathe was certainly new, and not as widely used as it should be. Mr. Adamson further wished for an explanation as to forging versus turning. A statement was made in the Paper that in many cases it was three men working on one piece and in others one man working on three pieces. The whole subject of roughing down in the lathe versus forging should be studied carefully. One method might be suitable for one shop, the other again in another. Mr. Adamson seemed to think that the waste of material in turning and reducing pieces was a formidable thing to consider, but the author thought it was as a rule one of the least items in connection with the matter. Mr. Adamson also said that the forging plants were something worth looking at in some districts in England, but he thought Mr. Adamson had made a very unfortunate reference, for of

(Mr. Orcutt.)

all the equipment the author had seen in this country, some of the forging plants for light work were about the worst.

Mr. Donaldson (page 58) brought out some very good points, one of them being that he thought the data mentioned would not bear very close comparison with work in this country. It did not, and was not intended to, but the figures given in the Paper as to speeds and possibilities of turning were possibilities which should be aimed at, and if they were fallen short of, an effort should be still made to come up to them. A great deal of machine work in England was capable of very much improvement if the details were studied. Some of the figures given in the Paper were taken from English practice.

Mr. Donaldson said that a great deal of work was done unaided by tools and machines, which could be done much more cheaply if the proper equipment was at hand. That was true. In many cases where very close work was done, it could still be done cheaper and better if a proper equipment was available. He had had many instances of that. A gentleman who was present that evening had to turn a great many pieces of one sort, and had been turning them to standard snap gauge, but recently he worked with a limit gauge, and gave the work to a cheaper employee, one who had had little experience compared with those who had previously done the work. He found that with the limit gauge piece after piece was turned within 1–10,000ths of an inch, and without any trouble. Before the limit gauge was used, the man was continually questioning and asking if it was close enough to gauge, but with the limit gauge he had no questions to ask, and was doing far finer work.

Mr. Donaldson then brought up the question of soft material (page 59), which was certainly an important matter. The practice of either the Americans or of the English might be condemned or lauded. Both had their faults and each might take a lesson from the other. The greatest fault he thought existed amongst English manufacturers: while the Americans made castings many times too soft, the English made them too uniformly hard. The lack of a laboratory and testing equipment did not enable them to vary the mixtures according to the work. For instance, in steam-engine practice, in cylinder work, it was perhaps necessary to make the parts hard. But a fly-wheel or other parts might be as soft as possible and could be very easily machined, if they were of a quality that would permit fast cutting. The modern foundry, when large enough to afford it, should support a laboratory by which the mixtures could be varied in accordance with the work, which would result in a large saving on a great many parts, and would give the uniformity that would allow maximum speeds and feeds. Mr. Donaldson further mentioned the difficulties of putting the shops in order by introducing new methods. That was very often done much cheaper and much more easily than was imagined. The author would never advocate anything revolutionary or any big change all at once in any shop, as any endeavour to do that was apt to be disappointing. The first question to be decided was whether a thing was good and whether it could be used, and then the attempt to use it could be made, not in too wholesale a manner, but by altering one detail after another. That would certainly lead to the progress which was to be desired, and without any very great expenditure at first. Besides, it afforded the great advantage of training the men while introducing the new methods, and that part of the matter was always a difficulty. The man must be taught to understand the machine he was using. Mr. Donaldson commended the adoption of the gauge system and appreciated it as much as anyone with the class of work he had to do. With regard to the tool-room, Mr. Donaldson commended it unreservedly, and he was certainly in a position to appreciate that matter. He brought up one point which he, the author, could hardly agree with, although in some cases it would be right, namely, that the tool-room should make everything. That was not true, especially of small shops where they could only afford to maintain a tool-room just sufficient to deal with their special needs, whereas if they went in for wholesale tool-making, they would find themselves behind and waste their energies in making things they could purchase much more easily. Colonel Crompton (page. 62), who had a different class of work to deal with, took the opposite view to Mr. Donaldson.

Mr. Donaldson referred to the apprenticeship question, and in answering him he would reply also to the question raised by Mr. Wright

(Mr. Orcutt.)

(page 81). The apprenticeship system of 100 years ago had its virtues. In the old guilds, which were formed for the protection and the monopoly of trade, the features of the apprenticeship embodied in that system were certainly in one respect commendable. One of the most important points was the constant contact that the master had with the apprentice, a thing which scarcely existed today under the factory system. The apprentice lived in the master's house; ate at his table; learned his trade under his master, directly taking his instruction from him; and those were things which did not occur very often at the present day, although such a system should be carried out to a far greater extent than was done. That was one of the good sides of the old system of apprenticeship which might be applied to modern methods. One of the bad sides, which had been handed down from practically the Middle Ages, was the time which apprentices were required to serve in engineering. It was determined that the seven years was none too long to learn a trade, and that view was still held. Why, he did not know. With modern machines a man in a few weeks very often attained a proficiency which it took years to reach before these machines were introduced.

He thought it best to give a short summary of the apprenticeship system which his own works had introduced, and which others had introduced, and that would deal with the question raised by Mr. Wright. There were several courses which apprentices might take. They might choose to become a general mechanic, tool maker, fitter, or a pattern maker, &c. For the machine constructor there was a course of four years. He had eight months each in fitting, turning and screw machine, planing and milling department; the remainder of the four years was divided between erecting, grinding, gear-cutting, smith shop, pattern shop and foundry. The fitter had eighteen months in the fitting. department, the remainder of the three years' term being spent in the turning, planing and milling, erecting, gear-cutting, and smith shop. The tool maker, the man who kept the tools and plant in order and maintained the efficiency of the factory generally, had twenty-four months in fitting, the remainder of his three years being spent in the turning, screw, planing and milling, grinding, polishing and smith shop, and in tempering. The turner had twenty-four months in turning and the screw machine department; the remainder of his three years being spent in the grinding, fitting, and smith shop. The planing and milling apprentice served three years similar to the turner. To become a smith, the apprentices worked also in the hardening and tempering room. The pattern maker had to serve six months in the foundry, and the moulder six months in the pattern shop. That general knowledge was necessary to give the apprentice the means of making his choice when he decided upon his speciality later on. It was the lack of that general knowledge, a knowledge and understanding of each other's departments and work, which caused a great deal of trouble in the shops.

Mr. Thornycroft was kind enough to make a few remarks on the Paper, and especially recommended the chucking system which was most wonderfully neglected in this country; and he was glad to see that Mr. Thornycroft thought well of it. Mr. Thornycroft also alluded to the fact that the general system mentioned could be adopted in a larger number of shops than was generally thought possible.

Colonel Crompton, in dealing with the Paper, first emphasized the viewing department, and that was a matter well worthy of consideration, because if operations and work were to be specialised, the responsibility was largely taken out of the hands of the workers, and that responsibility had to be placed somewhere. Its proper place was in an inspection department. Colonel Crompton also dealt with the tool-room question, taking the opposite view to Mr. Donaldson, as his works were different. He, the author, more thoroughly agreed with Colonel Crompton generally speaking than with Mr. Donaldson. With regard to portable machines, which were important for heavy work, engineers dealing with heavy parts should give attention to the matter, as it was extremely important. Colonel Crompton made one statement with which he could not agree, namely, that the fitter was going out of date. That was not true, and never would be true. Machines might be obtained which performed very accurate work, but that was a long way from getting rid of the fitter. The only thing possible to do was to reduce the fitter's work as much

(Mr. Orcutt.)

as possible, which meant economy in manufacture, but the fitter had to come in for the last touches, particularly in fine work and higher grade work. Repeated attempts had been made to do away with the fitter's work, but in the final fitting, for instance, of sliding surfaces, nothing had yet been found to equal the scraping by hand, or the fine work necessary when dealing with spindle manufacture. The spindles were lapped as truly spherical as possible. The bushes were all bronze and they were formerly scraped at once after they were rimmed; but now they were rimmed and ground, and by the grinding about six hours' work was saved in the scraping. That was a sample of reducing fitters' work. He thought Colonel Crompton was on the wrong tack, as in certain work it would be always necessary to rely on the fitter, and he himself would not like to see him go.

Mr. Weir (page 66) dealt with the Paper in a somewhat critical mood, but brought out some good points. He stated that it suffered somewhat from dealing with light manufacturing, and made the statement that the greater part of the work of this country was dealing with heavy manufacturing. The author had been unable to find any figures which would verify or condemn that statement, but he had a few which bore upon it, and his impression was that Mr. Weir was entirely wrong. In referring to the trades union list, he found in the total metal engineering and ship-building trades in the union, which only represented about a quarter of the workers of the country, there were 338,000 members. Out of those trades, which he should judge would be the large heavy work, there were 65,000, and of the amalgamated engineers there were 87,000. Adding the heavy trades and the amalgamated engineers together, it was even then less than half of the mechanical workers in the union, and he thought it would be safe to say that not more than one-third of the mechanical workers of this country were in heavy trades. That was worth bringing out, because the labour-saving machine and the great changes which must occur dealt more largely with light engineering work than heavy. In the heavy work the tool itself was very often merely a forged piece, while in light manufacturing the tools themselves were everything. Mr. Weir had a very fine shop, which he had seen a number of times, and he was very glad to have Mr. Weir's confirmation that a good floor actually paid, because that was so often doubted. Those who saw Mr. Weir's shop, and saw the wonderful order in which it was kept and their stores system, would no longer doubt its advantages. Many shops had no floors whatever, and he hardly thought that paid. Mr. Weir criticised the shop railways as useful only for heavy parts. He thought Mr. Weir was wrong, as a proper railway system throughout works, properly equipped, with the right trucks and specially worked-out rails, certainly did pay. The experience of many was quite the reverse of Mr. Weir's.

With regard to the space secured by order and cleanliness, that was another question on the subject of whether it paid to keep a shop in order and clean. He thought it did, and he thought the experiences of many would confirm that view. He had been in two shops only that week, and one was a very great contrast to the other. In one of them when he came out of the works he hardly knew what he had seen, there was such a pile of scrap and old machines, and dirt and dust. In the other it was quite different. It could be seen at a glance what was the quality of work being done and how it was being done, because everything was in order and the shop was clean. Mr. Weir also commended the general shop fittings in the way of work benches, stands for work, and facilities for holding parts, which were certainly worth attention. Many a good machine was unprofitable because it was in bad surroundings; and of course many bad plants were made profitable by keeping them in good surroundings. He also dealt with the question of the vertical boring mill, and had the same antipathy to it that Mr. Rowan had. Mr. Weir stated that for chucking operations the face-plate lathe appeared as good as any other machine, but appearances were very often deceitful. Some work was good for the horizontal machine and some was good for the vertical, and it was the same with the milling and planing. It was necessary to discriminate; but Mr. Weir forgot one point. He thought that the extra power gained in the mill was not of much advantage, but he should not forget that the heavy cut was not the only thing that absorbed power; high speeds and light cuts absorbed

(Mr. Orcutt.)

power also. Mr. Weir also mentioned the studding machine, which was worth bringing forward, as some of the work done by that machine was the smartest he had seen. It was a wonder to him it was not adopted more extensively, but Mr. Weir should also remember that others did the same work with the multiple drilling machines, drilling all the holes at once, and they made the same claims as to economy that he made for his machine.

Mr. Richardson (page 70) was another critic who brought out a few good points. He thought the Paper seemed to be a criticism of English methods, but that was not intended in any way, as the same criticism in many cases would apply to American shops or any others. Mr. Richardson further stated that the methods advocated were only possible where great repetition occurred. He had tried to explain that that was not so, and in the Paper he stated that those who thought it was were under a delusion. Mr. Richardson seemed to pose as one of the deluded; and said that so far as his experience went most modern methods had been adopted by leading works in England. He himself rather doubted that statement, without saying anything further. Again, Mr. Richardson stated that Americans overdid their specifications to magnify accuracy. That was a great mistake generally speaking, and he could claim some knowledge on this point. He thought that many times the aim of the Americans was to see what bad work they could do, and still have it good enough; and that was not a bad idea. Work that was better than good enough certainly was not economical and not called for, and one of the means by which the American did his work just bad enough to have it passed was the adoption of tools and gauges which would assist him to do it. It might be often noticed by visitors to the States that the American, with all his instruments, was doing in some cases work worse than was being done in this country, simply because he thought it was good enough.

With regard to Mr. Ransome's remarks (page 74), he specially commended the spirit in which he had criticised the Paper. If all the Papers read at the Institution were looked upon in the same manner, more would be obtained from them. Mr. Ransome asked how the high speeds of the milling cutters were obtained in the special case given. In that special case the iron was soft, and there was no call for the iron being hard. It had nothing to do with cutters. The speed mentioned gave a very good finish. Then he asked for the different speeds of planing machines. It was certainly a good thing to have different speeds, and it was very easily arranged by a variable speed counter-shaft. Then there was electric driving. He himself had seen a whole department of planers fitted with variable speed counter-shafts, and a great saving was claimed. Mr. Ransome also asked as to the quality of finish in fast grinding work. He thought he needed no other instance than the sample shown of the Corliss valve, Fig. 31, Plate 8, which was ground in thirty-seven minutes with an error of 0·0005 inch in length, and in diameter an error of 0·002 inch. Nothing more accurate could be required. It was a remarkably fast speed, of course. Mr. Ransome mentioned the collection of 5½ tons of cast steel when he established his tool stores, and that was a matter to be noted. Shops were often equipped with double and treble the amount of tool steel and tools required, simply because they were not kept in order, each man having his own kit.

Mr. Carnegie made one very good point (page 79) in stating that a distinction should be drawn between tool-rooms and tool-stores. Many manufacturers seemed to confuse the two, and some to think they were inseparably linked together. In many cases, especially in large shops, they had nothing to do with one another. Tool-stores were for the handy distribution of tools, and the tool-room was for the keeping up of the tool outfit.

Mr. Hill asked for the name of one shop in this country where one man attended six milling machines (page 79). He had the permission of the manufacturers to give their name, namely, Messrs. Hutchinson, Hollingworth and Co., of Dobcross. That firm had both union and non-union men in the works. Mr. Hill further asked why it took forty-five minutes to grind a certain sample shown, Fig. 31, Plate 8. That was an exception. It was a hollow tube very thin, and in fast grinding the pressures were very great. Forty-five minutes for this piece of work ought to satisfy the most exacting.

(Mr. Orcutt.)

He thanked Mr. Chambers and Mr. Hurry Riches for their remarks, and agreed that it was necessary to make improvements in one department at a time. By the time the whole of the departments had been gone through, it would be found that the first required further improvement, and so it would go on. Progress could only be made by the continued study of details. With regard to Mr. Wright's remarks on the apprenticeship question, he hoped he had given him a satisfactory answer. With regard to the grinding mentioned by Mr. Hurry Riches (page 82), he was glad to hear that this work was being done. The grinding mentioned in the Paper and shown by the samples was really the most revolutionary thing with which he was acquainted in workshop practice. Most workshop improvements were merely in detail, confined to putting in a good machine or tool here and there, and increasing the speed, &c.; but the grinding was really promising a revolution on account of the very fast speeds with which it would finish work. It came to this, that the equipment of any modern shop, where cylindrical surfaces had to be dealt with, must be altered very largely. Instead of considering how many lathes were to be put in, the question would be how many lathes and grinding machines. Mr. Hurry Riches had brought up the point of the smith shop versus the machine shop, and that, of course, must have consideration as well as other problems. He had rarely seen what he considered a good cutting-off department, an up-to-date one. In his own shops one man attended four cutting-off machines. The parts were cut off very cheaply, and in many cases it had been possible to do away with smith work, and do the work much more cheaply by systematising the whole thing.

In conclusion, he wished to thank those who had discussed the Paper, but would like to criticise the critics. It was said he was too general, but he thought his critics were too specific. Most of the critics had taken the standpoint of a special line, thinking of their own work too much. He had tried to avoid that in the Paper, and it only pointed to the fact that the knowledge of manufacturers was usually not general. They did not visit each other's works enough or exchange [ideas enough, or open their places freely to those who wished to acquire information and see how things were done. How many marine engineers thought they could learn anything in a cycle factory? Yet they could. He had never seen a shop yet in which he could not learn something. It was marvellous how many good things were hidden away in very bad shops. He hoped English engineers would change their practice somewhat. They were not liberal enough in exchanging ideas, visiting shops, and throwing open their method for the inspection of each other. If they would do that, it would be to the general good of the whole nation. He now came to the point which might satisfy some of the critics, and wished to state very briefly how he would classify the situation in English engineering. First, he would say that they were advanced in heavy milling, heavy planing, fast turning, and as skilled workers in many lines like ship-building, marine engines, high-speed engines, locomotive work, textile machinery, and cycle work. No one could excel them in those matters, and no product was superior. He thought that was glory enough for one country. Coming to the criticisms, those points which were generally understood but not well advanced were light milling, turret machine work, vertical mills, gear-cutting, which was very rapidly developing. Those points which were neglected by the majority of shops were gauges, chucking or proper boring outfit, grinding, tool-room practice, and use of small tools, and the apprentice question as applied to modern conditions. The next point was those things which were rarely attended to, which included the analysis of material, good shop fittings, and comfort and convenience for men. Those were dealt with in the Paper. There were two more points, which rarely received attention, first, the system of rewarding labour and cost-keeping, and, secondly, the social and economic conditions as affecting the efficiency of workers.

On the motion of the President, a hearty vote of thanks was accorded to Mr. Orcutt for his Paper and reply to the Discussion.

Communications.

Mr. WILLIAM DEAN, Member of Council, sent some memoranda describing the extent to which grinding machinery was in use at the Great Western Railway locomotive works at Swindon, and also furnished particulars of the leading descriptions of machinery.

The tyre grinding machines, referred to by the President (page 81), had been originally introduced to deal with the hardened steel-faced tyres, which had been brought into use about fifty years ago by the late Sir Daniel Gooch. Those tyres were superseded by the solid steel tyres, which had since been procurable; these they were able to turn with the high class tool steel now available, so that the use of the tyre-grinding lathes had been discontinued many years since.

GRINDING.

Slide-Bar Grinding Machine.—All slide-bars are ground. The machine is of the planer type. Upon the bed a box frame is bolted, which holds the slide-bar and also water, which just covers the bar. The work is passed under the emery wheel at a speed of about 12 feet per minute. A side traverse is given to the wheel, and is so arranged that its course is altered at each stroke of the table. The wheels used are of medium grain, and are 12 inches in diameter when new, with a width of 4 inches. Speed is 1,650 revolutions per minute, giving a surface speed of about 5,000 feet per minute. The time taken to grind a bar to a good face is about 1½ hours. The number of bars ground by each emery wheel is about 1,000, the wheel losing 3 inches of its diameter during the work. It is found necessary to keep the bearings always well adjusted, and the water clean.

Piston-Rod Grinder.—The best machine in use at Swindon for this purpose is one in which the rod, which is supported by dead centres on a travelling table, is traversed in front of the emery wheel. The wheel frame being rigidly fixed, the machine is arranged with two stones—one fine, the other medium grain. Either of these can be brought quickly to the working position without shifting the belt; this is a very useful feature, as it is possible by this means to use a roughing and finishing wheel. The roughing wheel is, as a rule, only brought into use for a badly scored rod. Care is necessary to get the best results. For instance, if enough water is not used, the side of the rod which has most to come off gets warmer than the opposite side, and it buckles, thus increasing the amount of metal removed from the heated side; an oval rod is the result.

Countershaft pulleys should be balanced to prevent vibration, The piston-rod is driven by a Clements driver, which ensures an equal drive from two opposite points. Rod revolves at about 140 revolutions per minute. Diameter of emery wheel when new is 1 foot. Revolutions 1,600 per minute. It takes $1\frac{1}{4}$ hours to grind $\frac{1}{64}$ inch off a steel piston-rod 3 inches diameter and 3 feet long. Speed of traverse is about 6 feet per minute. It has been found that if the stone has been run much above 1,600 revolutions per minute that vibrations occur, and show up on the rod.

If the speed is much below 1,600 revolutions per minute, flats are likely to occur on the rod.

Cutting Tools.—All the tools used on turret lathes, automatic and semi-automatic machines, are ground to special patterns, which are supplied by the makers of the machines. No one but the man in charge of the machines is allowed to do any grinding on them. The results are very satisfactory, and the tools last longer, and do better cutting than most of those ground by hand. A rectangular section of tool steel is used, and the tool is generally formed entirely by grinding, doing away with forging, unless for special shapes.

Turners are prejudiced in favour of grinding their own tools, but after a little use they see the superiority of machine-ground tools, and prefer to use them.

On the Gisholt tool-grinding machine, the emery wheel runs at a speed of 1,800 revolutions per minute. The stone is 9 inches in diameter at its largest part. Surface speed is about 4,500 feet per minute.

(Mr. William Dean.)

Lapping Machines for lapping out holes in case-hardened motion work. This work was formerly done with an ordinary lead lap run between lathe centre, and fed with emery and oil. The lapping machine has successfully replaced this. The main vertical spindle is bored eccentrically. In this is supported a second spindle, which is also bored eccentrically. In this hole runs a well-fitting spindle, upon the end of which a small emery wheel is fixed. The eccentricities of the two larger spindles are equal. It is possible to so lock the intermediate spindle with respect to the outer spindle, that the axis of the inner spindle shall coincide with the axis of the outer one, and, the whole system rotating, the emery wheel will simply revolve upon its own axis.

Should it be desired to lap the largest hole within the capacity of the machine, this is effected by so placing the spindles that the two eccentricities are added together, and the radius of the circle described by the axis of the inner spindle is equal to their sum. Hence, by adjusting and locking the two outer spindles, holes whose radii differ by amounts lying between zero and the sum of the two eccentricities can be lapped with the same wheel, which, revolving at high speed, is slowly carried round the surface of the hole. The spindle is also moved up and down vertically, so that the emery wheel shall come in contact with all parts of the work, so that there are three motions to the machine:—

1. Rotation of the small grinding spindle.
2. Slow rotation of the main spindle to carry the wheel-spindle round the surface of the hole.
3. A vertical motion.

Cutting speed of wheel, about 5,000 feet per minute.

Disc Surface Grinder.—One of the most useful grinding machines they have had is the disc grinder. It is used in the tool shop for grinding up surfaces true and square with each other or at any angle that may be required. Emery cloth is secured to the face of the discs by glue, and it gives excellent results. Different grades of emery are supplied. The diameter of the discs, which are detachable, is 1 foot 6 inches, and speed 1,200 revolutions per minute.

Great Western Railway.

Grinding Machinery at Swindon Works.

	Locomotive.	Carriage and Wagon.
Grindstones 6 feet and over	23	8
,, 4 feet and under	27	17
Emery Grinding :—		
Tools	27	13
Twist Drills	5	4
Milling Cutters	2	2
Dressing Castings	7	—
Tubes	2	—
Polishing	2	—
Piston Rods	3	—
Nuts, &c.	1	—
Double Lapping (Case-hardened Work)	1	—
Lapping, &c.	1	—
Bench Grinders	4	5
Knife Cutters	—	1
Plane Irons	—	1
Circular Saws	1	—
General	7	1
Mould Irons	—	1
Links, &c.	1	—
Emery Filing and Finishing :—		
General	—	1
Tube Ferrules	2	—
Emery Band	2	—
Cock Grinding	1	—
Buffing	17	3
Slide-Bar Lapping	12	—
Saw-Sharpening	1	4
Whetting Stone	—	1
	149	62
Total	211	

Piston-Valve Grinding on Landis Machine.—These valves, 6½ inches diameter, gave a lot of trouble at first to grind them fine enough for the purpose for which they were required. They are put into the

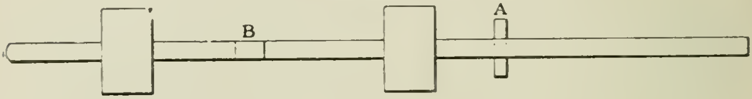
(Mr. William Dean.)

bushes a gauge fit. A steady was used on spindle, but with this the results were not satisfactory. The present method, which gives every satisfaction, is as follows :—

A steady is used on the spindle at A, Fig. 36 (page 106), and the portion at B is ground true for about $1\frac{1}{4}$ inches wide. The steady is then removed to position B, and the grinding proceeded with. A thin wheel about $\frac{5}{8}$-inch thick is found the most suitable, giving better results than those of greater thickness.

Water for keeping the work cool is taken direct from the main, it having been found that if the water was used over and over again, as is the case when the supply pump attached to the machine is in operation, that a certain amount of grit got on the wheel which caused cutting.

FIG. 36. *Grinding Piston Valves.*



Disc Grinding Machine with Renewable Burrs.—Used for grinding angle iron and other parts of engine frames. The work is traversed across the face of the stones. Nine stones are let into recesses in a disc, and secured by wedges. The wheel revolves at about 800 revolutions per minute. Its diameter is about 2 feet 6 inches over the stones. The bed of the machine has a pivoted table mounted upon the travelling bed. By this means it is possible to present the face of the work to the stones at any desired angle.

Mr. RICHARD B. HODGSON, in congratulating the author on his Paper, wrote that he thought the subject was a difficult, important, and far-reaching one; and it was really remarkable how much valuable matter the author had compressed into so short a space. For convenience he had tabulated his comments, which were intended rather as confirmation of, and addition to, the author's conclusions than a criticism of his work.

Gauges.—For some years past manufacturing engineers had taken advantage of the various forms of gauges, particularly the use of the micrometer for measurements. It was astonishing, therefore, that manufacturers generally, particularly those engaged upon metal-working and the allied trades, had not given more attention to the subject of standardizing their methods. The importance of this was brought forcibly under the writer's notice recently, in relation to the present system of gauging wire and rolled metal sheets. He found that between twenty and thirty wire-gauges, each differing from the other, were now being used in British and American factories; and, considering that each of these gauges was held by one manufacturer or another to be a standard gauge, it would be seen that a great deal of inconvenience and trouble arose when manufacturers were working one with the other. A glance at the gauge table, which he had previously published,* would convince an engineer how great were the troubles that nine gauges would give by their irregular numbers. He would like to know why the Whitworth standard had not long ago been adopted for sheets and wire, or any other work where fine measurements were required.

Grinding.—The use of emery grinding machines has become so extensive in all modern works, and the technical press has given so much attention to American machines of this class, that it was interesting to note British manufacturers were now producing some very smart grinding machines, one of which† provided for a plentiful supply of water to the work when being ground, without detriment to the working parts of the machine.

With regard to grinding flat surfaces, the author would probably know that machines were in successful operation at several large engineering works, dealing with large hardened flat surfaces.

Polishing.—As illustrating the downfall of the engine-lathe, "turners polishing and lapping their own work," the writer knew of one engineering works that made a speciality of steel mandrils used

---

* "Practical Engineer," 20th September 1901.

† "Engineering," 6th December 1901.

(Mr. Richard B. Hodgson.)

for drawing German Silver tubes; these mandrils were some 6 to 8 feet in length, and when turned must be polished or lapped, until absolutely parallel and without a scratch upon them. This was carried out in the engine-lathe by using powdered emery and a lead-ring in the form of a clamp, an operation which frequently occupied from twenty to thirty hours. This was an unfortunate waste of time, as compared with the operation mentioned by the author (page 21), where a shaft, 4 inches diameter by 3 feet long, was ground and finished in six minutes.

Drilling and Jig Work.—The manufacture of a cycle or motor-car driving-chain was a good example of what could be accomplished in a good drilling machine, aided by the use of a suitable jig. Such work of course required to be performed within 0·001 or 0·002 inch limit; for taking a block-chain of 1 inch pitch and 52 inches long, which contained 104 holes, a variation of 0·001 inch in each hole would result in a chain being one-tenth inch longer or shorter in the whole length. In some instances, with female labour, this class of work was actually carried out with remarkable rapidity, and so accurately that fifty chains were assembled to their total lengths and did not vary more than 0·062 inch; this was a far better result than was expected from an experienced mechanic upon machine or tool-work, and it was obtained by the use of a small vertical sensitive drilling machine and suitable jig. A point to be observed was that to secure such accurate work in large quantities, it was absolutely necessary that the work be performed upon a vertical machine, and that each hole be drilled twice. The first or smaller drill was to be passed through the work by using the jig; the second or finishing drill might then be passed through without a jig, to ensure the holes being all of the same diameter. The principal points to be observed when drilling small work by jig were as follows:—

(1) Drill to run perfectly true and at the proper speed.

(2) Jig to rest loosely upon an horizontal table (not held in a machine vice).

(3) A plentiful supply of suitable lubrication for the cutting of the drill.

(4) The drill or the work, as the case might be, to be fed forward by lever, pinion, and rack (not by screw and hand-wheel), as by using a hand-lever, the operator had more control over the drill, and less number of drills were broken.

Small Tools.—The use and advantages of a properly organised tool-stores has been so frequently demonstrated in engineering establishments, that it became the duty of British engineers to give expression to their experience in this direction for the benefit of manufacturers other than engineers and machinists. That there was a need for this was instanced by the fact, that in one large works, employing 1,000 pairs of hands, upon recently opening a workman's tool-drawer it was found to contain sufficient tools to supply the greater part of the factory. So deep and well stocked was the drawer that it exhausted six hours of hard work to sort and tabulate the various tools contained therein. This was the more urgent and important, since so large an amount of capital was invested in the tool-drawer of that particular factory, which might be otherwise invested if the works had its own organised tool-stores.

Tool-Room.—Many opinions have been put forth in the British technical and daily press concerning the struggle with American competition. But when the author said that " the very best skill and intelligence obtainable should be employed in this, the tool-room department," he introduced a question that had hitherto received scant attention, but which, if studied thoroughly, would fully repay the efforts of earnest attention, namely, that of the head tool-maker.

Having had the opportunity of studying closely both British and American methods, he could truly say that American engineers and manufacturers did make a practice of carefully selecting their managers, foremen, and heads of departments; they were also ever ready to encourage both the heads and under-workmen to bring intelligence into their work. Taking any first-class American firm, the following was found :—

(1) The works manager must be a thoroughly practical mechanic, or, in other words, a man who has " gone through the mill," having

(Mr. Richard B. Hodgson.)

learned his trade and being able to compete as a journeyman, but not a man who, so to speak, has merely walked through the shops.

(2) The foreman, or head of each department, must be a man who was thoroughly up to his business; in fact, he must be able if necessary to take hold of the tools from any workman's hands, and instruct him how best to perform a particular operation.

(3) Each workman was paid according to his merit. There was no hard and fast rule as to standard wage; he was paid upon the principle that any workman who, by his superior intelligence, energies, and abilities, could execute double the work was naturally worth better pay. From this it followed that should the employer obtain men of this class, they not only were able to make better profits from the workman's labour, but the greater output was obtained without the use of additional machinery.

(4) At intervals the works manager, foreman, and heads of departments, met the general manager for an hour's consultation; at such times any new ideas, suggestions, and likely improvements, that might tend to benefit the concern and make larger profits, were discussed. Should any workman have a suggestion to make, it was brought before the meeting by his foreman, and properly thrashed out and recognised at the proper time. This and similar arrangements had the great tendency to bring about an esprit de corps between heads of departments and workmen, and created a feeling of individual interest amongst all concerned in the welfare and prosperity of a manufacturing establishment.

The Apprenticeship Question.—This was a very broad and many-sided question. Things have changed much during recent years, and improvements appeared so rapidly in the different branches of all professions, that it was absolutely necessary for each individual to specialise in his own line. As one who had had some experience both as technical teacher and as foreman of departments in various manufacturing concerns, he ventured to offer the following brief suggestions. Taking a youth of fourteen years, his advisers should be careful that they did not encourage him to have too many irons in the fire. He might study many sciences in their elementary form, but when he reached the more advanced stages he would intuitively find himself deficient in the one science, mathematics, essential to the solution of problems which confronted him. It was not to be expected of any man that he should be a thorough master of both practical and theoretical engineering; it was necessary for the practical mechanical engineer to commence as a shop-lad and gradually pave his way from machine to machine, to find himself at the age of twenty-one years only just ready to go out into the world to engage on new sections, taking him all his time to keep pace with his fellow-workmen.

Assuming that a youth had received a fair school training, including a grounding in mathematics, and was intended to be a *practical* mechanical engineer, in addition to his special every-day working experiences, he should attend evening classes, and thoroughly study mechanical drawing and applied mechanics, giving as much of his spare time as possible to improve his mathematical knowledge. The youth, who was to become a theoretical engineer, in addition to his work in whatever special branch he might be engaged, could not do better than make himself a thorough master of mathematics and chemistry. Each would then have the foundation laid, after which they would be able to use their own discretion, as to what other sciences was necessary for their special branch of either practical or theoretical engineering to enable them to take their respective places in the engineering world.

Mr. WILLIAM SCHÖNHEYDER wrote that he fully appreciated the Paper, thoroughly agreed with nearly all the author had said, and believed it would be of great benefit to many engineers. But there were just two words in it to which he would take exception, as they not only did not express the meaning which they were intended to convey, but also already meant something different. One word was "chucking," which was evidently intended to mean some process of drilling or boring or turning in a lathe (either vertical or horizontal) with sundry tools, such as twist drills (short or long), reamers, &c., so as to produce first-class work. But chucking already meant the process of securing firmly and truly any piece of work to be operated

(Mr. William Schönheyder.)

upon, no matter whether it was to be roughly or finely finished, hence appliances as "scroll-chuck"; "three-jaw chuck," &c. The other word was "screw-machine"; this the writer would take to mean a machine for producing screws, and not, as was evidently meant, a "copying machine," that is, a machine for producing exact copies from either a turned article or a flat template. These two words had been, he understood, introduced from America, and were certainly not objectionable on that account; but while he was fully anxious to see as many as possible of the best American machine methods introduced and applied in this country, he did not therefore see either a necessity or an advantage in the introduction of the two words mentioned. Either "boring" (or "fine-boring") and "copying" seemed to the writer quite correct and sufficient expressions.

RECENT DEVELOPMENTS IN THE GAS-ENGINE.

A LECTURE

By Professor T. HUDSON BEARE, F.R.S.E., *Member*, of Edinburgh,

AT A MEETING OF THE GRADUATES ON

Monday, 10th February 1902.

Professor Alexander B. W. Kennedy, LL.D., F.R.S., *Past-President*, in the Chair.

In selecting the period to which I propose to limit my review of gas-engine development, I was guided by the fact that in the year 1888 a very elaborate series of trials of gas- and steam-engines suitable for electric lighting purposes were carried out by a committee appointed by the Society of Arts. The results of these trials were published in the following year, and a Paper descriptive of them was read before the Society by one of the leading members of that committee—Dr. Kennedy—on 28th March 1889. The engines submitted to that committee for test probably indicated the high-water mark which had been reached in efficiency of design and in efficiency of the utilization of the heat up to that period.

Of gas-engines three types were tested: the Atkinson, or cycle gas-engine, the Griffin engine, and the Crossley engine. The Crossley engine worked on the well-known De Rochas cycle, and thus had one explosion in every two revolutions of the crank when running at full load; the Griffin was a double-acting engine with a scavenger stroke, and therefore obtained at full load one explosion for one and a half revolutions of the crank; and the Atkinson, though single-acting, with its peculiar mechanical arrangements, had one explosion for every revolution at full load.

The Crossley engine was one of the type which had then come into use, in which the slide-valve had been displaced by lift-valves, and the old method of ignition by the slide-valve flame had been replaced by hot-tube ignition. These changes, only recently made, and the simultaneous introduction of the scavenger stroke in the Griffin type of engine seemed to afford, as it were, convenient means for dividing off the gas-engines which had been in use up to that period from those which have been constructed since 1889. It is these facts which led me to select the year 1888 as the starting point from which to proceed.

The Society of Arts' trials were remarkable both on account of the extreme care with which all the operations of the tests were carried out, and also from the carefully calculated heat balance-sheets which were drawn up as a result of the trials.

No attempt was made in the trials to measure either the temperature of the exhaust or the quantity of air admitted into the cylinder with the gas; but by the use of formulæ based on the well-known physical laws of permanent gases, and by making certain assumptions as to the constancy at all temperatures of the specific heats of the constituents of the charge and of the products of combustion, Dr. Kennedy was able to calculate both the temperature of the exhaust gases and the quantity of air admitted for each charge. To do this, it was necessary to know the temperature of the charge which filled the cylinder at the moment compression was about to begin. This temperature could not be directly measured, but Dr. Kennedy was of opinion that it would not differ much from that of the cooling water as it left the jacket, and for the purposes of the calculation it might be considered to be the same. The results obtained by Dr. Kennedy from the calculations, whether the assumptions were strictly valid or not—and on this I shall have something to say later on—were no doubt fairly close in agreement with the actual facts, and though it is a twice-told tale, it is worth while drawing attention again to a very striking proof of this. In a test of another gas-engine, at a slightly earlier date than the above trials, he was able, in consequence of similar calculations, to express the opinion that combustion was not complete when the exhaust took place; and as the result of suggestions he made, more economical results were obtained in this engine by altering somewhat the valve arrangements. The following brief summary of the results obtained in these classic trials may be of service for reference purposes:—

Table of Results obtained in the Society of Arts' Trials in 1888.

Engine.	Duration of Trial.	Compression Pressure (Absolute).	Indicated Horse-Power.	Brake Horse-Power.	Total Gas used per Hour.		Calorific Value of Gas per Cubic Foot.	Thermal Efficiency of Engine.	Mechanical Efficiency.
					Per Indicated Horse-Power.	Per Brake Horse-Power.			
	hrs.	lbs. per sq. in.					B.T.U.	p.c.	p.c.
Atkinson	6	50·3	11·15	9·48	19·22	22·61	633	22·8	85
Crossley	6	76·3	17·12	14·74	20·76	24·10	626	21·2	86·1
Griffin	6	58·7	15·47	12·51	23·10	28·56	624	19·2	80·9

In the Atkinson engine 27 per cent. of the heat received was rejected in the jacket water, and it was estimated that 37·9 per cent. passed away with the exhaust gases. (Dr. Kennedy was of opinion that in this engine combustion was not complete at the time exhaust began.) In the Crossley engine 43·2 per cent. passed off in the jacket water, and the calculated loss in the exhaust gases was 35·5 per cent. In the Griffin engine these figures were 35·2 per cent. and 39·8 per cent. respectively. The calculated maximum temperatures reached were 2,530° F., 3,000° F., and 2,120° F., while the temperatures when the exhaust valve opened were about 1,560° F., 1,670° F., and 1,400° F. respectively.

Up to this period I think I am right in saying that the limiting size of any gas-engine which had been put upon the market was 40 horse-power, and the patent rights connected with the "Otto" patent of 1876 had, to a certain extent, hindered the rapid development of the gas-engine industry, on account of the high prices which were then charged by the manufacturers. But, on the other hand, possibly the existence of this patent and the resultant continuous efforts made by other firms to produce an engine of merit and quality equal to those built by Messrs. Crossley Brothers, may have been of advantage, because most of the rival makers tried to adopt some other cycle than the De Rochas; and their efforts led to the design of the double-acting engine and other types, in order to obtain one or even two impulses per revolution in place of the one impulse per two revolutions of the "Otto" type.

There is very little doubt, I am sure, that the amount of research and ingenuity displayed in connection with these attempts have done much to secure the great advance we have witnessed during the last ten or fifteen years. Unfortunately, however, to my mind, when the "Otto" patent expired in 1890, the bulk of the makers abandoned the various types which they had evolved and fell back on the simple "Otto" cycle—a cycle which, I consider, is by no means an ideal one for many of the purposes to which it is proposed to apply the large engines now being built. But within the last few years there has been a tendency to revert once more to gas-engines which have a greater frequency of impulse than one per two revolutions, when running under full load.

I have already mentioned that there were two distinct and important improvements introduced just about the time of the Society of Arts' trials, and I propose to say something more in detail with regard to the effect of each.

The first point to which I wish to draw attention is the so-called scavenging principle. In the Griffin engine this was secured by the following method of working. Between the exhaust stroke and the next suction stroke for drawing in a fresh charge, a pair of strokes was interposed, during which a charge of pure air was drawn in and then swept out again; thus, if the engine had been single-acting, there would have been only one impulse for every three revolutions; but as the engine was a double-acting one, two impulses were obtained every three revolutions under full load.

The effect of the scavenging stroke, however, was extremely important, the hot products of combustion were swept out, and there was comparatively little risk of any premature explosion owing to the fresh charge on entering the cylinder meeting hot exhaust gases, and in addition the scavenging charge helped to cool the cylinder sides, and in this respect assisted the cooling water of the jacket. Shortly after this period, Messrs. Crossley Brothers determined to obtain the scavenging effect by a somewhat different device. It had long been known that, in a long exhaust pipe during the exhaust, pulsations or waves of pressure were set up in the pipe, and it occurred to those responsible for the design of these engines, that advantage might be taken of this fact to sweep out the last remains of the burnt gases by means of fresh air. For this purpose the exhaust pipe has to be of a length of about 65 feet (if desired, quieting chambers can be used as usual at the outer end of this pipe), and the time of opening and closing the air and exhaust valves also requires some modification. The exhaust valve is held open a little longer than was formerly the practice, and the air-valve being also open and the pressure in the cylinder (owing to the effect of the pulsation in the exhaust pipe) being slightly below atmospheric pressure, the incoming fresh air enters with sufficient energy to drive out in front of it into the exhaust pipe all that remains of the previous burnt charge.

There is no doubt that, as in the Griffin engine, and in all others where this scavenging principle has been adopted, it has secured the possibility of much higher compression of the charge, without any risk of causing a premature explosion. Leaving a portion of the burnt charge in the cylinder to mix with the incoming charge was an obstacle to the safe use of high compression.

The marked economy brought about by this change, and the accompanying higher compression pressure which it was possible to adopt, is shown by the figures which I will now give for a test of one of these engines of more or less the same size as was tested by the Society of Arts.

A test of a 4-horse-power nominal scavenging type by Mr. Dugald Clerk in August, 1894, gave the following figures:—

Compression Pressure, Absolute. lbs.	Gas per I.H.P. Hour. cub. ft.	Gas per B.H.P. Hour. cub. ft.
102·2	14·5	17

A Stockport "Otto" of 9 horse-power nominal, tested by Mr. A. R. Bellamy, of Messrs. Andrews and Co., gave the following result:—

Compression Pressure, Absolute. lbs.	Gas per I.H.P. Hour. cub. ft.	Gas per B.H.P. Hour. cub. ft.
104·7	17·6	20·75

Comparing these results with those of the Society of Arts' trials, we see at once the immense gain in economy in five or six years. Taking the brake horse-power as the basis, we find an improvement of nearly 25 per cent., due largely to improvement in design, increased compression, and the use of the scavenger principle.

There was, however, still an obstacle to any marked advance in the size of gas-engines. As long as large gas-engines were compelled to use the ordinary lighting gas they could not hope to compete with the steam-engine, and a great deal of the advance of the last few years has been due to the success which has been met with in the design of gas-producers of various types.

Up to the year 1889 not much had been done in this line, but owing to the successful efforts of Mr. Dowson, Dr. Mond, and others, the problem has been solved, and as a necessary corollary to the large gas-engine we have the gas-producer.

The fundamental principle involved in the gas-producer is the conversion of the carbon of the solid fuel into an inflammable gas. Now, it is well known, that if CO_2 is passed through a sufficient depth of incandescent carbon it is converted into an inflammable gas CO or carbon monoxide. Therefore, if air is blown through incandescent C, we get CO, and if the whole of the carbon could thus be converted, we should get an efficiency of the gas-producer of

70 per cent., owing to the lower heating value of CO as compared with C, and to the fact that the heat carried away by the CO from the producer has to be wasted to a large extent, because the gas must be cooled down before it can be used in the gas-engine cylinder. But there is another chemical reaction which will produce the same effect. If steam be passed over highly incandescent carbon, the oxygen of the steam will combine with the carbon, and the hydrogen is liberated; thus, $H_2O + C = H_2 + CO$. In the actual apparatus the coal or coke is put into a brick-lined producer, thoroughly ignited, and brought up to a good heat by means of a blast, and then steam and air are blown in, in fixed proportions, and the resultant gas cooled and sent away to a gas-holder; the Dowson gas-producer works upon this principle. To start the producer, the upper cover being removed from the fuel hopper, a fire is lit upon the bars and air blown through; the fuel which is to be gasified—it may be either anthracite or coke—is then added from above till the contents are highly incandescent, and fill the producer to a depth of about 18 inches, the gases which are given off during this time being burned at the open hopper. As soon as the fuel is perfectly incandescent, the inner and outer valves of the hopper are shut, and after this the gas generated flows away through a pipe through cooling and scrubbing plant to the gas-holder; it enters the gas-holder through a coke scrubber, forming part of it, and then passes through another scrubber to the gas-engine. The complete plant therefore requires a small boiler, fitted with superheating tubes, in order to supply the superheated steam to work the air-injector, and thus force the mixture of air and steam into the incandescent fuel; and fresh fuel is constantly fed in through the hopper. Ordinary Dowson gas requires for its complete combustion about 1·13 times its volume of air (coal gas requires from five to seven and a half times its own volume of air), and its heating value is about one-quarter that of an average coal gas; hence for some time it was difficult to get a very high mean pressure in engines using it, owing to the dilution of the charge with residual burnt products; but here, again, the scavenging principle has made a great and marked improvement.

In the Lencauchez producer an attempt is made to save some of the heat leaving the producer in the hot gases, and to utilize slack or other fuel having much volatile carbon.

The gas generated is led off from the centre of the producer instead of the top, and on its way to the holder it passes in a pipe through an air and steam heater and a boiler ; the steam generated in this latter (not under pressure) passes at once into the air and steam heater, where it mixes with air blown in by a positive fan, and thence the mixture of air and steam passes to the bottom of the producer. The fuel at the top of the producer is always thoroughly coked before it reaches the highly incandescent portion of the producer, and hence any tar products are broken up and reduced to fixed hydro-carbons.

The latest development of this phase of gas-engine work is the Mond gas, from which so much is confidently expected in the near future. Dr. Mond's producer is adapted for the use of cheap fuel and the recovery of ammonia. The experimental work has been carried on for many years (since 1879), and the results now achieved are exceedingly good. It has lately been described fully before the Institution of Civil Engineers (in 1897), and still more recently (in 1900) before the Institution of Mechanical Engineers by Mr. Humphrey, so that it is hardly necessary to do more than give a very brief outline of the process. Common bituminous slack is fed into the hoppers and then descends in charges of 8 cwt. to 10 cwt. into the producer bell; the first heating of the slack distils off the hydro-carbons, etc., which then pass down through a hot zone, where the tar is broken up. In the body of the producer there is the usual air blast which has been saturated with steam and superheated, the fundamental difference between this and other producers being the fact that a very large quantity of steam is used, about 2½ tons per ton of slack. The large amount of steam used keeps down the temperature and prevents the destruction of the ammonia. Half a ton of this steam is decomposed per ton of slack, giving nearly 29 per cent. of free hydrogen in the final producer gas. The gases and undecomposed steam on their way from the producer pass first through a tubular regenerator (through which the incoming air blast passes in the opposite direction), then through a washer, where by means of a spray of water they are cooled down to some 194° F., and then to a lead-lined tower filled with tiles, where they meet a down-coming current of acid liquor containing sulphate of ammonia with a small amount of free H_2SO_4; in this tower, therefore, the ammonia of the gas is recovered. Finally, the gases pass to a gas-cooling tower, where they meet a current of cold water, and are then fit for use.

One of the secrets of the success of this producer is the principle of the regenerator which is adopted throughout the process. The water heated by cooling the gas in the gas-cooling tower is pumped into the air-heating and saturating tower to warm the air, and after being cooled in doing this, it goes back once more to the gas-cooling tower, and so on. One producer of the ordinary size can deal with about 20 tons of slack per 24 hours, and about 140,000 to 160,000 cubic feet of gas are produced per ton, the value of the sulphate of ammonia recovered is about 8*s.* a ton of fuel at present prices, the calorific value of the gas (saturated at 59° F.) is about 148 B.T.U. per cubic foot, and about 1·15 volumes of air are needed to burn one volume of the gas.

The following figures are given by Mr. Humphrey as a typical analysis of Mond gas (dry):—

CO = 11 per cent. (dry volume)
H = 29 ,,
CH_4 = 2 ,,
CO_2 = 16 ,,
N = 42 ,,

The proportion of the charge by weight is as follows:—

	Per cent.	
Fuel (dry slack)	= 16·03	
,, (moisture)	= 1·52	
Steam (from air-heating tower)	= 14·75	= 38·12
,, (added)	= 23·37	
Air	= 44·33	

Mr. Humphrey estimates that he gets in this gas about 84 per cent. of the original heat in the fuel, but this calculation seems to ignore the heat required to generate a considerable portion of the large quantity of steam used in the process (some of this steam is, as noted before, obtained by the regenerator working); but in criticising this statement it must be remembered that this excess of steam is only needed when it is desired to recover the ammonia.

The great value of these gas-producers when used in connection with large gas-engines is shown in the results obtained during recent tests of very large engines, the figures of which I will give you. The first one I propose to deal with is a test of a large gas-engine using a cycle very different to that of the "Otto" cycle in many respects.

Koerting two-cycle 350 *B.H.P. Gas-engine.*—This engine is double-acting, the stuffing-box being water-jacketed. There is one admission valve at either end of the cylinder driven by the crank-shaft; the exhaust ports are at the centre of the cylinder, and are uncovered by the piston as it gets to the end of its stroke. The gas and air have each their own double-acting pump, of equal stroke, and driven by an auxiliary crank set at 110° ahead of the main crank; their valves are of the piston type driven by an eccentric on the crank-shaft, the gas and air being each delivered through their own pipe into openings in front of the admission valve.

Working Cycle.—At the end of the working stroke the piston uncovers the exhaust openings, and the spent products rush out of the cylinder; when the pressure is about atmospheric, the admission valve for that end of the cylinder opens, and air and gas enter and sweep out the rest of the burnt exhaust gases. On the return stroke, as soon as the exhaust closes, the charge is compressed, and then, when the crank is on its dead centre, ignition takes place, and the working stroke is secured; thus each revolution of the crank gives one explosion. To prevent the new charge coming in contact with the hot exhaust gases, and a premature explosion taking place, a scavenger charge of air is interposed between them. The diameter of the air-pump is so proportioned that its capacity is more than is needed for the supply of the air for combustion, and the piston valves of the gas-pump are so set that a certain portion of the charge of gas drawn in by this pump on the suction stroke goes back to the gas-main, the valve which controls this not closing till the gas-pump piston has completed four-tenths of its return stroke; meanwhile the air-pump has been delivering air freely into the air-pipe and the chamber in front of the admission valve, and has also filled the greater part of the gas-pipe with air. Thus, when the admission valve is opened, all this scavenging air has to enter the cylinder and sweep out the products of combustion before any gas can enter. In order to distribute the incoming charge thoroughly through the cylinder, there is a projection just below the admission valve, against which the entering stream of gas and air strikes. Ignition is obtained electrically, and there are two ignition ports at each end.

Governing is secured by varying the period during which, on the return stroke of the gas-pump piston, the connection between the pump and the gas-main is kept up, and communication with the gas-pipe to the cylinder kept shut, with full load as stated before this continues for four-tenths of the stroke; at lighter loads it is longer.

The cooling water for the piston and its rod is conveyed by tubes of the telescoping type moving with the crosshead.

A test of this engine was carried out by Professor Meyer in June, 1900.

Dimensions of Engine and Methods of Test.—Cylinder diameter, 21·6 inches; stroke, 37·7 inches; air-pump diameter, 24·4 inches; gas-pump diameter, 19·6 inches; stroke of both, 27·5 inches. Diagrams were taken every five minutes, and the brake horse-power was determined electrically. The gas used was producer gas from a Koerting producer using gas coke, its heating value being determined by a Junkers calorimeter.

Results.

Indicated horse-power, motor	533
,, ,, pumps	62
Net indicated horse-power	471
Brake horse-power	334·7
Mechanical efficiency (neglecting pumps)	71 per cent.

Results (continued).

Heating value of gas (lower), per cubic foot	129 B.T.U.
Gas used per net indicated horse-power per hour	59·1 cubic feet.
Gas used per brake horse-power per hour	83·1 ,,
Heat efficiency per net indicated horse-power	33·5 per cent.
Heat efficiency per brake horse-power	23·8 ,,
Mean revolutions	101

It is interesting to note the pressures reached in the cylinder at full load. The compression pressure was 12½ atmospheres absolute =184 lbs. per square inch, and the maximum pressure was 27½ atmospheres absolute=404 lbs. per square inch.*

In his Paper on "Power Gas and Large Gas-Engines," Mr. Humphrey gives the following results obtained in a six-hour trial of a 400-horse-power Crossley engine using Mond gas and coupled direct to a dynamo. This engine has two cylinders, each 26 inches in diameter by 36 inches stroke, one on either side of the crank-shaft, both connecting-rods working on to the one crank-pin.

Brake horse-power	359·6
Revolutions per minute	148·5
Mechanical efficiency (including fluid losses)	83 per cent.
Mond gas used per brake horse-power per hour	75·5 cubic feet.
Calorific value of gas per cubic foot (lower value)	142·5 B.T.U.
Thermal efficiency of engine on brake horse-power	23·76 per cent.

In this engine the compression was kept at a comparatively low figure—under 100 lbs. absolute, and as a result the efficiency is not as high as it otherwise would have been.

A 500 horse-power "Premier" gas-engine, also in use at Winnington, gave better results even when working at two-thirds full load. This engine has two cylinders of the tandem type, each 28⅛ inches in diameter by 30 inches stroke.

Brake horse-power	368·2
Revolutions per minute	128·05
Mechanical efficiency (including fluid losses)	75·3 per cent.
Mond gas used per brake horse-power per hour	69·2 cubic feet.
Calorific value of gas per cubic foot (lower value)	143·8 B.T.U.
Thermal efficiency of engine on brake horse-power	25·6 per cent.

---

* Professor Meyer on "Engines Driven with Power and Blast-Furnace Gas."—*German Gas-Lighting Journal*, 1900.

The compression pressure adopted in this engine was much higher than in the Crossley engine, being over 140 lbs. absolute. Mr. Humphrey stated in the discussion on his Paper that the Crossley engine had improved its performance since the above test, and was now working with an efficiency 1 per cent. greater than it gave on the day of the official trial.

Use of Blast-Furnace Waste Gases.—About 1894 attention began to be drawn to the possibility of using blast-furnace waste gases in place of producer-gas for working gas-engines, and there is very little doubt that the idea was taken up at almost the same time in Great Britain, in Belgium, and in Germany.

Mr. Thwaite, who was the first—in May 1894—to propose such a scheme in England, was enabled in February 1895 to fit up an "Acme" gas-engine at Wishaw, at the Glasgow Iron and Steel Works, where it drove a dynamo. This engine had a 12-inch cylinder with a 20-inch stroke; it ran at 190 revolutions, and generated about 15 horse-power, and was tested in August 1896. The blast-furnace gases used had a heating value of 126 B.T.U. per cubic foot, and contained 27·8 per cent. of combustible gas; the furnace at the time was supplying 170,000 to 180,000 cubic feet of such gas per ton of iron made. The engine used about 84 cubic feet of gas per horse-power-hour; or, in other words, one electrical horse-power was secured for 1·6 lb. of coal burnt in the furnace—that is to say, 1·6 lb. of coal in the furnace not only did the smelting work as before, but the otherwise waste gases from this amount of fuel were able to give in addition one electrical horse-power. The fuel in this blast-furnace was coal, and therefore the waste gases had to be purified from ammonia and tar before they could be sent to the gas-engine. This somewhat complicated the process.

The next attempt in England was in 1897, at the Frodingham Works, where a 15 horse-power "Acme" was set to work with a waste gas of a heating value of 102 B.T.U. per cubic foot. This engine ran with a consumption of 110 cubic feet per horse-power per hour.

The development in England, however, of the utilization of blast-furnace gases has been somewhat slow, and our enterprising rivals across the North Sea have been much quicker in taking up this question than we have been in Great Britain. There are, however, a 400-horse-power Thwaite-Gardner engine at the Clay Cross Ironworks working a vertical air-blower; a 500-horse-power Crossley at Wolverhampton, driving direct air-blowing cylinders, the engine cylinders (there are two, working on to the same crank-pin) being 31 inches in diameter, and the stroke 36 inches, and the speed 130 revolutions a minute; and a 600-horse-power Seraing type engine is now in process of erection at Middlesbrough.

In Belgium the first idea of the utilization of blast-furnace gases was due to the Cockerill Company. This company was at that time about to embark in the manufacture of gas-engines, and eventually decided to adopt the "Simplex" single-cylinder four-cycle engine, with electrical ignition. This type of engine, as it happened, was very suitable for experiments on the utilization of blast-furnace gas, as, in order to work with a high compression, the end of the cylinder had been carefully rounded inside, thus doing away with all sharp corners and edges where dust could collect and cause trouble. Ignition in this engine is obtained by means of a slide-valve, the electric arrangement securing a continuous stream of sparks in the ignition chamber, and then at a certain definite time the slide-valve puts the cylinder in communication with this ignition chamber. The engine also has special arrangements in regard to the inlet valves; there are two—one for air and one for gas—opening into a mixing chamber, and from this chamber the mixed charge passes into the cylinder by means of a third inlet valve, which is water-jacketed, and is the only one of these inlet valves subjected to the direct effects of the explosion.

An 8-horse-power engine of this type was set to work in 1895, and ran for a considerable period of time, using gas from the blast-furnaces; the quantity of gas used was about 187 cubic feet per horse-power-hour.

The company were so well satisfied with the result of this experiment, that in 1898 an engine of 150 brake horse-power was put down to work an air-compressor. This engine was tested by Professor Witz in 1898, and was found to have a thermal efficiency of about 20 per cent., the compression pressure adopted being 114 lbs. per square inch.

In November 1899, a larger engine, rated as a 600-horse-power engine, was erected, and this has also been most carefully tested both against a brake and when working the air-compressing cylinder. This engine has a cylinder 51 inches in diameter with a 55-inch stroke, the air-cylinder having the same stroke and a diameter of 67 inches; the motor plunger piston is jacketed as well as the cylinder barrel and end.

Results of Tests when Driving Blowing Cylinder.

Indicated horse-power	886
Brake horse-power (deduced from work done in compressing air)	725
Revolutions	93
Mechanical efficiency	81 per cent.
Maximum pressure	250 lbs. absolute.
Heating value of the blast-furnace gas per cubic foot (lower value)	99·7 B.T.U.
Gas used per brake horse-power-hour	101 cubic feet.
Thermal efficiency on the indicated horse-power	31·2 per cent.
Thermal efficiency on the brake horse-power	25·3 ,,

The compression adopted in this engine was 135 lbs. absolute.

It should be stated that the heating value of the fuel was determined experimentally, both by a Junkers calorimeter and also by a bomb calorimeter, and it also was in addition calculated from the chemical analysis. The mean results varied from 99 to 111 B.T.U. per cubic foot, the lower value being given by the Junkers calorimeter.

In Germany the first attempt at this utilization of blast-furnace gases was in 1895, at the Hörde Iron Works, in Westphalia, where a 12 H.P. "Otto" type of engine was tried, the compression being 6½ atmospheres. So satisfied again were the users with the result, that they determined to proceed with the experiments, and they adopted as their type of gas-engine the Oechelhaeuser two-cycle gas-engine, which has only so far been used with blast-furnace gases. The arrangements of this engine are somewhat like those of the Atkinson differential gas-engine. There is one long horizontal water-cooled cylinder, in which there are two pistons working in opposite directions; the front piston is attached by its connecting-rod to a crank set at 180° to two other cranks, which are driven by connecting-rods attached to the crosshead of the back piston. This back crosshead also works the piston of a double-acting air-pump, delivering pure air on one side and mixed gas and air on the other. There is no cam-shaft and practically no valves; the pistons themselves open and close the admission and exhaust, the exhaust being so arranged as to prevent any possibility of any of the exhaust gases remaining in the cylinder to mix with the fresh charge. The cycle of this engine is as follows: the two pistons being as close together as possible, and the space between being filled with a mixture of gas and air at a pressure of about 135 lbs. absolute, the charge is fired electrically and both pistons move out, making their working stroke. As the main pistons reach the end of their outstroke the front one uncovers the exhaust openings, and the other immediately after uncovers a port through which clean cool air at a slight pressure enters the cylinder; this acts as a scavenger charge to sweep out all the remains of the previous burnt charge, next the same piston opens a second port by which the compressed charge from the air-pump enters the cylinder, driving out the scavenging air. On the return stroke of both pistons the ports are closed and the charge is compressed, ready to begin the cycle again. The cylinder is most carefully water-jacketed, and the scavenging air at Hörde is supplied from the blowing engines driven by the gas-engine. The cylinder for an engine designed to give 1000 horse-power is 36·8 inches in diameter, and the 600-horse-power engine has two 300-horse-power cylinders, each 19 inches in diameter by 31½ inches stroke, running at 135 revolutions. The Deutsche Kraft Gas Gesellschaft are now making very large engines of this type, engines to give 1000 horse-power with a single cylinder, and they have proposed to construct a 2000-horse-power single-cylinder engine.

One of the main difficulties, which had to be overcome in the use of blast-furnace gases for gas-engine work, was the removal of the dust which was carried out from the blast-furnace along with the gases. It was thought at first that much trouble would also be caused by the considerable variation in the composition of the gas and by its high temperature; but both these latter difficulties turn out in practice to be of no great importance. The variation in the composition is prevented by mixing the gases delivered from several furnaces, and as a result the average composition does not vary to any marked extent, and as the proportion of hydrogen present in the gases is small, a small variation makes but little difference. The high temperature difficulty is also got rid of by the cooling, which is brought about in the process of cleansing the gases from the dust; the dust is mainly metallic particles mixed with lime; a certain amount is deposited in the exhaust mains as they pass from the blast-furnace.

In connection with the trouble experienced from the dust in the blast-furnace gases, attention may be drawn here to a Paper read by M. Greiner before the Iron and Steel Institute in May, 1901.* M. Greiner stated in that Paper that the Cockerill Company had had a 200-horse-power gas-engine running at Seraing for three years, since 1898, which has never required the cylinder to be cleaned once on account of the dust, though the engine ran night and day, and the blast-furnace gases were used entirely without any purification; and that a 600-horse-power gas-engine at the same works, also using unpurified gases, had so far given no trouble.

On the other hand, at Differdingen, where the Cockerill Company were putting up nine 600-horse-power gas-engines, great trouble had at once been experienced, due to the fact, as was ascertained on making investigation, that the blast-furnace gases at Differdingen contained on an average from 4 to 5 grammes of dust per cubic mètre, while at Seraing the proportion was not more than 0·25 to 0·5.

---

* Journal, Iron and Steel Institute, 1901, No. 1, page 56.

M. Greiner instituted an inquiry into the variation of dust in blast-furnace gases, and came to the conclusion that with furnaces using hematite ores, as a rule the amount of dust was small; but where oolitic ores were used a great deal of dust was carried forward, even when the gases passed through long lengths of pipe before they reached the point where they were utilized, and that it was impossible to separate the dust by using long lengths of pipes or any other such simple plan; the dust was in such a fine state of division that it was readily carried forward. He said there were at present practically two plans in use for cleansing the gases: one, which may be called the "static system," where the gases are passed through a series of scrubbers (which are sheet-iron towers containing coke or sawdust cooled with water spray), a plan due to Mr. Thwaite, to whom so much of the credit for the use of blast-furnace gases belongs; and the other, which may be called "dynamic," where the gas is passed through an ordinary centrifugal fan into which a jet of water enters at the axial part. The latter was the more convenient for use at Differdingen, and apparently experience has shown that the expectations formed as to its working have been justified. The plan adopted there was to use a fan about 60 inches in diameter running at 900 revolutions a minute; through this the gases pass, drawn in by the central aperture, and a stream of water also enters the axial part through a pipe about 1 inch in diameter; the gas is driven out through the ordinary discharge, and the dust and water pass away in a 2-inch pipe, taken off from the lower part of the casing. Examination of the gas showed that, before entering the centrifugal fan, it contained as much as 4 grammes per cubic mètre, and after passing through only 0·25 gramme, and it was then in a fit state for use in the gas-engines. The water used amounted to about 1 to 1½ litres per cubic mètre. It was stated that the total cost of this apparatus for dealing with the amount of gas which would be required for six 600-horse-power engines was only £400, and M. Greiner strongly advocated the adoption of a similar plan for purifying the blast-furnace gases, even when they were only burnt in heating stoves. It should be mentioned, however, that in the discussion on this Paper a good deal of scepticism was expressed, mainly by English iron and steel experts as to whether purification by this simple process would prove successful in the long run; it seems to have been satisfactory so far, where it has been tried.

The heat value of blast-furnace gases necessarily varies very much with the type of furnace, the rate of working it, and the proportion of the charges and various other conditions.

As a result of a series of analyses of blast-furnace gases in England, Belgium, and Germany, it appears that about 28·8 per cent. of the gas is carbon monoxide, about 2·5 per cent. hydrogen, about 7·25 per cent. carbon dioxide, and about 61·3 per cent. nitrogen. If a blast-furnace is in good work as regards the reduction of the metal, the more CO_2 in the exhaust gases the better, and of course this is a distinct disadvantage when the waste gases are used for gas-engine work. The heating value per cubic foot ranges from about 105 to 115 B.T.U., using the higher value for the hydrogen constituent; but, as the proportion of hydrogen is comparatively small in these gases, there is not much difference in the heating value, whether we take the higher or lower values for the hydrogen.

Opinions differ very much as to the probable amount of power available by the utilization of blast-furnace exhaust gases, and probably some of the estimates that have been made are somewhat rash.

Mr. Lürmann, the German authority, expressed the opinion that of the total gas produced in blast-furnaces, about 10 per cent. was lost in leaks in the pipe and in the smelting; about 28 per cent. was required for heating the blast, and that in most ironworks at the present day about another 40 per cent. was used for the generation of steam. This left about 22 per cent. passing to waste, and he estimated that there would be about 28 horse-power-hours available per ton of iron smelted, if this waste were utilized in gas-engine work. To take one example at Seraing, where about 600 tons of iron are made per day, there was waste gas sufficient to develop 17,000 horse-power; and in Germany, as a whole, where 7,400,000 tons of pig are made a year, he estimated there is available some

570,000 horse-power. Whatever opinion we may have as to these figures, there is no doubt that this plan of making use of gases, which were previously to a considerable extent wasted, is bound to have a great future. In a Paper read last March before the German ironmasters at Düsseldorf, Mr. Lürmann gave some statistics as to the amount of power now being developed in Germany from this source; at that time it amounted to a total of 44,000 horse-power, which is a somewhat remarkable record, when it is remembered that it is only five years since the idea was first mooted. In Belgium, France, and Italy there were engines developing about 17,000 horse-power at work.

Though it is never safe to prophesy, it is, as a rule, pretty safe to forecast future lines of development in engineering practice by carefully watching the present trend, and I do not think, therefore, I shall be too rash if I forecast for the utilization of blast-furnace gas a very remarkable future in this country.

In America, in place of the large engines using producer or blast-furnace gases, we have the Westinghouse three-cylinder type of engine using natural gases. Until quite recently—owing probably to the high price of coal gas—the gas-engine had not met with much success in the United States; but since the question was taken up by such an energetic company as the Westinghouse Company, a complete change has been brought about. Large three-cylinder gas-engines, developing from 600 up to 1,500 horse-power on the brake, are now being extensively used in central station work in suitable districts. The heating value of this natural gas being about 1,000 B.T.U. per cubic foot, it is a comparatively easy matter to govern these engines by controlling the richness of the charge, and thus ensure very steady running conditions. I have not been able to find any very complete records of lengthy tests of this type of gas-engine, but the heat efficiency when using about 10 cubic feet of gas per brake horse-power per hour appears to be 25 per cent.—a very good figure indeed.

In considering the future prospects of large gas-engines, the questions of freedom from breakdown and steadiness of running are most important. My own experience, extending now over a period of twelve years, is that in the smaller sizes the gas-engine is singularly free from breakdown troubles, and costs but a merely nominal sum annually in repairs, even when you work the engine under a heavy and constant load. For larger engines we now have equally strong testimony from those who have used them, the long period during which the large engines at Seraing have run without any need of repairs, and the testimony of Mr. Humphrey as to the long runs of a 60-horse-power nominal Crossley engine, are fairly conclusive. This latter engine ran for two years for 96·6 per cent. of the whole possible time of running, and had actually run for six months, day and night, without a single stop, and this with only the most trifling repairs. Such evidence requires no comment from me; it is clear that gas-engine makers, by careful attention to details and by extreme care in the jacket arrangements, are able to turn out large gas-engines which will give as little trouble in working as the very best types of steam-engines now on the market. As regards steadiness of running, we have again plenty of testimony. In the case of the two large engines at Winnington, already mentioned, the variation of speed was comparatively small; with the ordinary "hit and miss" method of governing, the total variation was under 2 per cent., and with the engine allowed to explode every possible time, the variation was under $\frac{2}{10}$ of 1 per cent. It is clear that one of the chief obstacles to the more extended use of gas-engines in central station work has been removed when such steady running as this can be guaranteed.

I cannot within the limits of this lecture deal with the question of relative cost of gas- and steam-engines, but all the figures I have been able to collect go to prove that the gas-engine supplied with producer or blast-furnace gases is a most formidable rival, even to the finest high-speed steam-engine; while my own experience convinces me that for driving a small workshop, where the power used fluctuates a good deal, the small gas-engine even using town gas is much more economical than a similar sized steam-engine and boiler. I would refer you for further details to the elaborate cost figures given in Mr. Humphrey's Paper, and in several other recently published papers.

I cannot conclude this brief summary without some reference to the two valuable Reports already issued by the Gas-Engine Research Committee of the Institution of Mechanical Engineers, though, of course, it is quite out of the question that I should attempt to summarise two Papers which are themselves a condensed account of experiments lasting for many months. I would merely say that the difficulties already encountered in measuring the temperatures in the cylinder show how extremely difficult this problem is; and until some knowledge is available as to how the temperatures vary throughout the mass of gas present at any instant in the cylinder, I am afraid that the use of these measured temperatures in any calculations as to loss or gain of heat during expansion or compression is liable to quite as serious errors as those introduced by the assumptions made by Dr. Kennedy in connection with the Society of Arts' trials. When one remembers that it is the temperature absolute which is used in these calculations, an error of even 50° F. in the accuracy of the temperature, at the instant that compression begins, does not seriously throw out the final results, nor does the assumption of uniformity of specific heat; comparing the specific heat at constant volume of nitrogen at 1,000° F. with that at 32° F., the increase is only some 7 per cent., and therefore the mean specific heat over the range differs by a still smaller percentage from the usually accepted value. As long, therefore, as we have to depend, either on measured temperatures when we can only measure it at one point of the mixture, or on calculations based on an analysis of exhaust gases in order to determine the temperature of the mixture at the point where compression begins, it appears that we may still safely continue to use the older approximate methods, especially when the engine has good scavenging arrangements, and none of the burnt charge remains in the cylinder.

It is interesting to note in the last report of the Committee that the increased efficiency due to raising the compression pressure before firing from 55 lbs. to 124 lbs. amounted to 2·7 per cent., or an increase of about 20 per cent. The figures below, extracted from the Report, show the gradual increase in efficiency:—

Compression Pressure. lbs.	Efficiency on B.H.P.
55	13·2
71	14·0
93	13·4
124	15·9

The Chairman said that some years ago Professor Beare and himself had attended many lectures together—the one as lecturer, and the other as student. To-night, however, their original positions were reversed, to the great enjoyment of himself. He thought that Professor Beare had managed capitally to compress into a small space of time the modern history of the gas-engine. It was the fault of the subject and not of the lecturer that each point had had to be so briefly touched upon. In the days when he himself made the trials for the Society of Arts, gas-engines of 16 and 20 horse-power were thought to be of considerable size. Moreover gas-engine makers did not at that time encourage but rather threw cold water on the introduction of larger sizes. Now things were altered, large engines were being continually made, special researches (particularly by our Institution) were carried out as to their theory and mode of working, and the era of a large industry in the manufacture of large gas-engines seemed to have commenced. He wished to express on behalf of those present to Professor Beare their heartiest thanks for the interesting lecture they had heard, and the great appreciation of the trouble he had taken in coming specially from Edinburgh for this purpose.

The vote of thanks was carried with acclamation.

Professor Beare thanked them most heartily for the kind way they had received his lecture, and the patience with which they had listened to him. He felt that, in compressing a great amount of material into so short a time, he had only been able to touch briefly

(Professor Beare.)

upon the main outlines of gas-engine history of the last eleven or twelve years. He would therefore earnestly recommend them to refer to the original sources of information, which were to be found in the Proceedings of this and kindred Institutions.

Mr. P. H. STEVENS, Graduate, in proposing a vote of thanks to Professor Kennedy for acting as Chairman that evening, desired to say how much the Graduates appreciated the keen interest taken by the Council in helping them to make the Association a success.

Professor KENNEDY suitably acknowledged the vote.

The Institution of Mechanical Engineers.

PROCEEDINGS.

21 FEBRUARY 1902.

The FIFTY-FIFTH ANNUAL GENERAL MEETING was held at the Institution on Friday, 21st February 1902, at Eight o'clock p.m.; WILLIAM H. MAW, Esq., President, in the Chair.

The Minutes of the previous Meeting were read and confirmed.

TRANSFERENCES.

The PRESIDENT announced that the following two Transferences had been made by the Council:—

To the class of Members.

BUTCHER, MALCOLM HENRY (*Assoc. Mem.*), . .	London.
MACKENZIE, THOMAS BROWN (*Graduate*), . .	Glasgow.

The following Annual Report of the Council was then read:—

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR 1901.

For presentation to the Members at the Fifty-Fifth Annual General Meeting on Friday the 21st February 1902, at Eight p.m.

The Council have the pleasure of presenting to the Members the following Report of the progress and work of the Institution during the past year.

His Majesty the King has conferred the honour of a Knight Grand Cross of the Royal Victorian Order on Sir Frederick Abel, Bart., K.C.B., that of Knighthood on Mr. Robert Harvey, and that of Companion of the Bath on Lieutenant-Colonel R. E. B. Crompton, R.E.

In recognition of his distinguished services to science, Lord Kelvin, who acted as President of the International Engineering Congress in Glasgow, has been elected an Honorary Life Member of the Institution.

At the end of 1901, the number in all classes on the roll of the Institution was 3,490, as compared with 3,165 at the end of the previous year, showing a net gain of 325. During the year there were added to the register 426 names; and the total deductions were 101, made up of 36 decease during 1900 (see Report of 1900: 35 + 1 subsequently), 41 resignations which took effect on 1st January 1901, and 24 removals.

The progress which has been made by the Institution since its establishment in its new quarters has been in every way most satisfactory and encouraging. At the end of the year 1898, when the Institution entered into possession of the new building, the number of members of all classes on the roll was 2,684, while during the succeeding three years the net gains were 238, 243, and 326 respectively, the total number on the roll being now, as already stated, 3,490. The membership at the end of 1898 has thus been increased by 30 per cent. during the last three years, and, what is still more satisfactory, the rate of yearly increase has been an augmenting one.

The following thirty-nine Deceases of Members of the Institution were reported during the year 1901 :—

Archer, David,	Birmingham.
Armstrong, George,	Wolverhampton.
Bailey, Wilfred Daniel,	Buenos Aires.
Bevis, Restel Ratsey,	Birkenhead.
Bruce, Graham Stewart,	Negapatam.
Burn, Robert Scott,	Edinburgh.
Clark, George,	Sunderland.
Clayton, William Wikeley,	Leeds.
Clowes, Edward Arnott (Associate),	London.
Collins, William Lorenzo (Associate Member),	London.
Corry, Edward,	London.
Crook, Charles Alexander,	London.
Fairbairn, Sir Andrew,	Leeds.
Forsyth, Robert Alexander,	Newport, Mon.
Gordon, Leslie (Graduate),	Stanmore.
Guthrie, Allan (Associate Member),	Glasgow.
King, John James,	Nottingham.
Laing, Arthur,	Sunderland.
Lewis, Joseph Slater, F.R.S.E.,	Manchester.
Logan, John Walker,	Cape Town.
Mackay, Charles O'Keefe,	Bolton.
Macnab, Archibald Francis (deceased 1899),	Tokyo.
Martin, George Best (Associate Member),	Birmingham.
Matheson, Henry Cripps,	London.
Munn, John Adam (Associate Member),	Calcutta.
Murdoch, Robert Macmillan,	Port Talbot.
Murray, Alexander John,	India.
Owen, Thomas,	Derby.
Pugh, Charles Henry,	Birmingham.

Pullar, Frederick Pattison (Graduate),	Bridge-of-Allan.
Rixson, Francis,	Sheffield.
Rowe, Almond,	Singapore.
Spencer, Thomas,	Newcastle-on-Tyne.
Thomas, William Henry,	London.
Walton, James,	Old Charlton.
Whiteley, William,	Huddersfield.
Widdowson, John Henry,	Manchester.
Wilson, Charles Louis Napoleon,	Rhodesia.
Wilson, John Charles,	Edinburgh.

The Accounts for the year ended 31 December 1901 are now submitted to the Members (see pages 146–9 and 150), having been duly certified by Mr. Robert A. McLean, F.C.A., the Auditor appointed by the Members at the last Annual General Meeting.

The total revenue for the year 1901 was £9,306 12*s.* 0*d.*, while the expenditure was £9,115 16*s.* 8*d.*, leaving a balance of revenue over expenditure of £190 15*s.* 4*d.* The financial position of the Institution at the end of the year is shown by the balance sheet. The total investments and other assets amount to £70,277 3*s.* 0*d.*, and, deducting therefrom the £25,000 of debentures and the total remaining liabilities, £3,525 19*s.* 6*d.*, the capital of the Institution amounts to £41,751 3*s.* 6*d.*, including the £4,237 L. and N. W. Railway 3 per cent. Debenture Stock set aside as the nucleus for a Leasehold and Debenture Redemption Fund. The remaining investments, consisting of £3,945 12*s.* Midland Railway 2½ per cent. Debenture Stock and £1,000 Consols (2¾ per cent.) are held by the Union Bank of London as security for an overdraft. The certificates of the securities have been duly audited by the Finance Committee and the Auditor. It should be noted that the sums of £506 and £89, received respectively for Entrance Fees and Life Compositions, have been carried direct to Capital Account in the present statement; and subscriptions received in advance for 1902, amounting to £94 10*s.*, have also been omitted from the Revenue Account. Had these three items been credited to Revenue, as was the practice in former years, the balance of Revenue over Expenditure for the year 1901 would have been £880 5*s.* 4*d.* instead of £190 15*s.* 4*d.*

The work of preparing the Sixth Report of the Alloys Research Committee—dealing mainly with the effect of annealing and tempering on the properties of Steel—was continued in the laboratories of Professor Sir W. C. Roberts-Austen at the Royal Mint and at the Royal College of Science until the end of October; and a full Report, which is now partly written, is expected to be ready during the ensuing year. One of the numerous Appendices to the series of Reports, namely, that dealing with the Microscopical Examination of the Copper-Tin Alloys, carried out by Mr. William Campbell, B.Sc., at the Royal College of Science, under Sir William C. Roberts-Austen, was read and discussed at the December Meeting of the Institution.

The Second Report of the Gas-Engine Research Committee was read and discussed at the October Meeting, and the Institution has agreed to provide during the coming year instruments for trials with a large experimental gas-engine which Professor Burstall is designing to form part of the power and lighting plant in connection with the new Birmingham University Buildings.

The Committee has been strengthened by the additions of Mr. Dugald Clerk and Mr. Herbert A. Humphrey.

The experiments at University College, London, on the Value of the Steam-Jacket were continued during the early part of the year with the old apparatus, but were interrupted by the removal of the Reporter, Professor T. Hudson Beare, to The University of Edinburgh. The apparatus has been removed from London to Edinburgh, and the Reporter is now designing several improvements in the valves for the admission and exhaust of the steam into the hot pots of the apparatus. As soon as these new valves are made, the experiments will be resumed, and it is hoped more satisfactory results will be obtained with this new apparatus.

The series of experiments at King's College on the compound steam-jacketed engine has been completed, and Professor David S. Capper has promised his Report early this year. A second series of tests with unjacketed cylinders has been commenced, and is being carried through at the same speeds and steam pressures as the first jacketed series. Direct comparisons can then be made both with and without steam-jackets.

The Council desire to record their thanks to the members and others who have given new books to the Library, also to the donors of various publications of societies and public authorities, and of technical periodicals, a list of which appears on pages 150 to 160.

The usual provincial Summer Meeting, extending over three days, was held in Barrow-in-Furness, when, amongst other Papers, valuable contributions on the local industries were presented by several of the engineering directors of Messrs. Vickers Sons and Maxim, and the Barrow Steel Works, and the engineers of the Furness Railway Company. These and other works, including the Hematite Iron Mines, were visited, and other excursions arranged to various places of interest. Mr. Archibald Miller kindly acted as Honorary Local Secretary, and the Members were hospitably received by the Mayor and Corporation, the Furness Railway Company, Messrs. Vickers Sons and Maxim, and the Millom and Askam Hematite Iron Company, and others.

Monthly Meetings of the Institution were held throughout the year, with the exception of May to September, while on three occasions extra meetings were held to continue important discussions. These meetings, with the Barrow Meeting, were occupied by the reading and discussion of the following Papers:—

Light Lathes and Screw Machines; by Mr. John Ashford.
Combined Trolley and Conduit Tramway Systems; by Mr. A. N. Connett.
Address by the President, Mr. William H. Maw.
Naval Ordnance; by Lieut. A. Trevor Dawson.
The Arrangement and Equipment of Shipbuilding Works; by Mr. James Dunn.
Barrow Docks and Approaches by Land and Sea; by Mr. Frank Stileman.
Review of Marine Engineering during the last Ten Years; by Mr. James McKechnie.
Some Work in the Development of a Motor-Car; by Mr. M. Holroyd Smith.

Second Report to the Gas-Engine Research Committee; by Professor F. W. Burstall.

The Balancing of Locomotives; by Professor W. E. Dalby.

The Microscopical Examination of the Alloys of Copper and Tin; by Mr. William Campbell, B.Sc.

The following Papers were accepted for publication in the Proceedings:—

The Barrow Hematite Steel Works; by Mr. Arthur J. While.

History of the Furness Railway Locomotives; by Mr. W. F. Pettigrew.

The attendance at these meetings has been very satisfactory, and, as mentioned above, the discussion on three occasions had to be adjourned to special meetings. The arrangements in the meeting hall for the exhibition of tools and specimens of work, as well as wall diagrams and lantern, have been much appreciated.

The Meetings of the International Engineering Congress at Glasgow, September 3rd to 6th, were well attended. The sittings of the Mechanical Section (III), which extended over three mornings, were carried out under the direction of the Institution, the President acting as Chairman of the Section, and two of the Vice-Presidents (Mr. Bryan Donkin and Mr. J. Hartley Wicksteed) as Vice-Chairmen. The following Papers were read and discussed:—

The Cooling of the Cylinders of High-Speed Internal-Combustion Engines, and its Effect upon the Power Developed; by Professor H. S. Hele-Shaw LL.D., F.R.S.

Trial of Steam Turbines for Driving Dynamos; by the Honourable Charles A Parsons, F.R.S., and Mr. G. Gerald Stoney.

Some Particulars of the Results of the Compound Locomotives on the Buenos Aires Great Southern Railway; by Mr. R. Gould.

The Rating and Testing of Electrical Machinery; by Mr. Gisbert Kapp.

Some Experiences and Results derived from the use of Highly Superheated Steam in Engines; by Mr. R. Lenke.

A Premium System of Remunerating Labour; by Mr. James Rowan.

Some Factors Affecting the Economical Manufacture of Marine Engines; by Mr. William Thomson.

Workshop Methods: Some Efficiency Factors in an Engineering Business; by Messrs. William Weir and J. R. Richmond.

The Adoption of the Metric System in our Workshops; by Mr. Arthur Greenwood.

The 100-Ton Universal Testing Machine with Variable Accumulator, at the James Watt Laboratories, Glasgow University; by Mr. J. Hartley Wicksteed.

A Regenerative Accumulator, and its Application for using Exhaust Steam; by M. A. Rateau.

Experiments on the Escape of Steam through Circular Orifices; by M. A. Rateau.

Power Required to Drive a Marine-Engine Works; by Messrs. James Crighton and W. G. Riddell.

Pneumatic Riveting, and other useful Applications of Pneumatic Tools; by Mr. J. C. Taite.

Agricultural Machinery in the Canadian Pavilion at the Glasgow International Exhibition, 1901; by Mr. G. Harwood Frost.

The Cassel Self-Regulating Water Wheel; by Mr. E. C. de Segundo.

These Papers, together with reports of the discussions, were published as a special part of the Proceedings, and members of other Sections of the Congress were allowed to purchase copies.

It is intended to hold the next Summer Meeting of the Institution in Newcastle-upon-Tyne.

The Graduates have held monthly Meetings and monthly Visits to Works during the Session. The attendance has been satisfactory, and each Meeting was presided over by a Member of Council. The following Papers were read and discussed:—

Electric Vehicles (Road); by Mr. J. S. Warner, of London.

Gold Extraction from Free Milling Ore; by Mr. H. H. Johnson, of Cape Town.

Motor Car Transmission Mechanism; by Mr. Alfred Marsden, of London.

Tin-Plate Manufacture; by Mr. W. H. Tregoning, of London.

The Mechanical Testing of Constructural Materials for Locomotives; by Mr. C. A. Embleton, of London.

Education of Naval Engineers; by Mr. W. H. Michell, of Greenwich.

At the January Meeting, Professor J. A. Ewing, F.R.S., delivered a Lecture on "The Structure of Metals," which was illustrated by lantern slides.

The Council have awarded a first prize to Mr. W. H. Tregoning for his Paper on "Tin-Plate Manufacture," which has been published in the Proceedings,* and two second prizes to Messrs. H. H. Johnson and A. Marsden for their Papers on "Gold Extraction from Free Milling Ore," and "Motor Car Transmission Mechanism" respectively.

The Council have joined with the Councils of the Institution of Civil Engineers, the Iron and Steel Institute, and the Institution of Naval Architects in forming a Committee to be called "The Engineering Standards Committee," for the purpose of recommending standard sizes for rolled sections, and other matters.

The question of standardizing pipe flanges, being of great importance at the present time, will be dealt with in a Paper to be read before the Institution at an early meeting.

The result of the Ballot for the election of President, two Vice-Presidents, and five Members of Council, to fill the vacancies caused by retirement, will be announced at the Annual General Meeting.

---

* Proceedings 1901, page 1273.

Dr. ACCOUNT OF REVENUE AND EXPENDITURE

Expenditure.

	£	s.	d.	£	s.	d.
To Expenses of Maintenance and Management—						
Salaries and Wages	2,417	3	0			
Postages, Telegrams, and Telephone	451	13	11			
Heating, Lighting, and Power	126	8	4			
Fittings and Repairs	132	15	1			
Housekeeping	131	2	5			
Incidental Expenses	63	4	11			
				3,322	7	8
„ Printing, Stationery, and Binding—						
Printing and Engraving Proceedings	1,625	18	3			
Stationery and General Printing	571	7	6			
Binding	33	4	11			
				2,230	10	8
„ Rent, Rates, Taxes, &c.—						
Ground Rent	875	17	2			
Rates and Taxes	773	8	11			
Insurance	23	9	9			
				1,672	15	10
„ Meeting Expenses—						
Printing	385	19	11			
Reporting	68	11	10			
Diagrams	13	4	9			
Travelling and Incidental Expenses	163	6	2			
Glasgow Congress	73	9	5			
				704	12	1
„ Books purchased				13	0	4
„ Expenses in connection with Research Committees				147	10	5
„ Debenture Interest				1,000	0	0
„ Interest on Bank Loan				53	15	2
„ Special Expenses—						
Conversazione	159	8	0			
Dinner Expenses	9	6	7			
				168	14	7
„ Depreciation on Furniture and Fittings				67	2	0
Total Expenditure				9,380	8	9
Less outstanding expenses at 1st Jan. 1901, already included in last year's accounts				264	12	1
				9,115	16	8
„ Balance, being excess of Revenue over Expenditure, carried to Balance Sheet				190	15	4
				£9,306	12	0

FOR THE YEAR ENDED 31st DECEMBER 1901. *Cr.*

Revenue.

				£	s.	d.
By Subscriptions for 1901				8,518	0	0
„ Subscriptions previously in arrear, paid during 1901	375	0	0			
Less estimated amount credited in last account	301	10	0	73	10	0
„ Interest, &c.—						
From Investments	179	17	11			
Income Tax refunded	11	12	1	191	10	0
„ Reports of Proceedings—						
Extra Copies sold				148	7	0
„ Debenture Transfer Fees				0	5	0
„ Estimated value of subscriptions in arrear (*being equal to the amount received in* 1901)				375	0	0
				£9,306	12	0

Dr.

BALANCE SHEET

	£ s. d.	£ s. d.	£ s. d.
To Debentures—			
250 *of* £100 *each at* 4%, *redeemable in* 1917, *or at par at any date after* 1st *Jan.* 1908, *on six months' notice to holder*			25,000 0 0
„ Cash—			
Union Bank of London, overdraft		1,741 3 7	
Less *In the Secretary's hands*		32 9 4	1,708 14 3
„ Sundry Creditors—			
Accounts owing at 31st *Dec.* 1901 (*since paid*)		1,620 4 6	
Willans Premium Fund		4 15 4	
Unclaimed Debenture Interest (coupons not presented)		97 15 5	1,722 15 3
„ Subscriptions paid in advance			94 10 0
„ Capital of the Institution:—			
Balance at 31st *Dec.* 1901		35,905 5 11	
Add:—			
Excess of Revenue over Expenditure for the year ended 31st *Dec.* 1901	190 15 4		
Amount received from Life Compositions during 1901	89 0 0		
Amount received from Entrance Fees during 1901	506 0 0		
Amount set aside in excess of requirements in 1897 *and* 1898 *for Redemption of Debentures now written back, being* £5,000 *less* £3,151 9*s.* 6*d. cost of L. & N. W. Ry.* 3% *Debenture Stock*	1,848 10 6	2,634 5 10	38,539 11 9
Amount invested in £4,237 *London and North Western Ry.* 3% *Debenture Stock and interest thereon set aside for Redemption of Debentures and Institution's Leasehold Property, see contra*			3,211 11 9
(*The Market Value of this Stock and interest at* 31st *Dec.* 1901 *was about* £4,428.)			
			£70,277 3 0

Signed by the following members of the Finance Committee:—

W. H. MAW,
BRYAN DONKIN,
HENRY DAVEY,
E. B. ELLINGTON,
H. GRAHAM HARRIS.

AT 31st DECEMBER 1901. *Cr.*

		£	s.	d.
By Investments	Cost	3,707	15	2
£ 3,945 12*s. Midland Ry.* 2½% *Debenture Stock.** 1,000 2¾% *Consols.** (*The Market Value of these investments at* 31*st Dec.* 1901 *was about* £4,254.)				
„ Investment of Amount set aside for Redemption of Debentures and Institution's Leasehold Property, *see contra* . . .		3,211	11	9
£4,237 *London and North Western Ry.* 3% *Debenture Stock cost* £3,151 9*s.* 6*d. and* £60 2*s.* 3*d. interest thereon received* 15*th July* 1901 *to be invested.* *This stock with its accumulating interest is set aside for the above purpose.*				
„ Subscriptions in Arrear, *estimated value* (*being equal to the amount received during* 1901)		375	0	0
„ Furniture and Fittings (*less depreciation*)		1,274	17	10
Books in Library, Drawings, Engravings, Models, Specimens, and Sculpture (*estimate of* 1893)		1,340	0	0
„ Amount in Union Bank to meet unclaimed Debenture Interest (*coupons not presented*)		97	15	5
„ Proceedings—stock of back numbers, *not valued.*				
„ Institution House, expenditure in previous years		60,270	2	10
		£70,277	3	0

* See page 140.

I certify that all my requirements as Auditor have been complied with, and I report to the Members that I have audited the above Balance Sheet, dated the 31st December 1901, and in my opinion such Balance Sheet is properly drawn up and exhibits a true and correct view of the state of the affairs of the Institution as shown by its Books.

ROBT. A. McLEAN, F.C.A.,
Auditor,
1 Queen Victoria Street, London, E.C.

15*th January* 1902.

WILLANS PREMIUM FUND.

Investment £159 8*s.* 5*d.* of India 3% Stock . . . . cost £165 5*s.* 0*d.*

Dr.	£	*s.*	*d.*	*Cr.*	£	*s.*	*d.*
To award to Capt. H. R. Sankey	14	6	0	By Interest, 1898, 1899, 1900	14	6	0
„ Balance, held in trust .	4	15	4	„ Interest 1901 . . .	4	15	4
	£19	1	4		£19	1	4

Audited, certified, and signed by the names on pages 148–149.

(For the Declaration of Trust, *see* Proceedings 1901, page 16.)

LIST OF DONATIONS TO THE LIBRARY.

BOOKS (in the order received).

Digest of British and Foreign Patent Laws, by A. J. Boult; from the author.

Experimental Engineering, Vol. I, Engines and Boilers, by Prof. W. W. F. Pullen; from the author.

Fergusson's Surveying Circle and Percentage Tables, by J. C. Fergusson; from the author.

Die Hundertjahrfeier der Koeniglichen Technischen Hochschule zu Berlin, 18–21 October 1899; from the Rector.

Exercises in Graphic Statics, with examples of its application to practical designing of constructional ironwork, by G. F. Charnock; from the author.

Standards of Length and their practical application, edited by G. M. Bond; from Mr. Purdy.

Report of the Tramways Sub-Committee on the Systems of Traction in various towns, and on Electric Tramways for Leicester; from Mr. E. G. Mawbey.

L'Artillerie à l'Exposition de 1900, by Le Colonel X; from Madame Dunod.

Popular and descriptive account of the Steam Engine, and on Steam Navigation (1836), by C. F. Partington; from Mr. W. H. Cullen.

Central Electrical Stations, by C. H. Wordingham; from the author.

Hydraulic Mining, Part IV, Dredging for Gold, by Capt. C. C. Longridge; from the author.

Notes sur la Construction du Pont Alexandre III, with Atlas, by MM. Résal and Alby; from M. A. Alby.

3,800 Miles Across Canada, by J. W. C. Haldane; from the author.

The Elements of Machine Design, Part I, by Prof. W. Cawthorne Unwin; from the author.

Festschrift zur XXXXII Hauptversammlung Vereins Deutscher Ingenieure in Kiel 1901; from the Society of German Engineers.

Report of His Majesty's Commissioners for the Paris International Exhibition, 1900 (2 Vols.); British Official Catalogue, Paris Exhibition, 1900; from Colonel Sir Herbert Jekyll, K.C.M.G.

Manual of the Japanese Laws and Rules relating to Patents, Trade Marks and Designs, by W. Silver Hall; from the author.

Contribution à l'Étude des Alliages, 1896–1900; from the French Society for the Encouragement of National Industry.

The Management of Engineering Workshops, by A. H. Barker; from the Institution of Junior Engineers.

British South Africa Co.: Reports on the Administration of Rhodesia, 1898–1900; from Mr. Henry Chapman.

Les Grands Moteurs à Gaz et l'Utilisation des Gaz de Haut Fourneau, by Jules Deschamps; from the author.

Communications presentées devant le Congrès International des Méthodes d'essai des Matériaux de construction, Paris, 9–16 Juillet 1900; Procès-verbaux sommaires, by the Secretaries of the Congress; from the French Minister of Commerce.

Practical Mathematics for Beginners, by Frank Castle; from the author.

Illustrated Description of the Works and Manufactures of Messrs. Vickers, Sons and Maxim, Ltd.; from Mr. James Dunn.

Golden Tips, a Description of Ceylon and its great Tea Industry, by H. W. Cave; from Mr. H. H. Tarver.

Sanitary Fittings and Plumbing, by G. Lister Sutcliffe; Roads, their Construction and Maintenance, by Allan Greenwell and J. V. Elsden; from *The Builder.*

Water-tube Boilers, by L. S. Robertson; from the author.

Memoria acerca del Estado y Progreso de las Obras de Saneamiento de la I. Villa de Bilbao, 1 Julio 1899–31 Diciembre 1900; from Mr. T. A. Greenhill.

Engineering Index, Vol. III, 1896–1900; from Mr. H. H. Rhodes James.

The Economic Disposal of Towns' Refuse, by W. F. Goodrich; from the author.

Report of the Board of Education, 1900–1901 (3 Vols.); from Sir W. de W. Abney, K.C.B., F.R.S.

Costruzione ed Esercizio delle Strade Ferrate e delle Tramvie; from Mr. S. Richardson Blundstone.

Reports on the Inspection of Mines in India, 1899 and 1900; from the India Office.

The following Official Publications from the Government of New South Wales:—Annual Report of the Railway Commissioners for the year ending 30 June 1901; Annual Mining Report of the Department of Mines and Agriculture, 1899; Conditions of Tendering, &c., for the proposed Sydney Harbour Bridge (with lithographs); Iron Ore Deposits of New South Wales, by J. B. Jaquet; Mineral Resources of New South Wales, by E. F. Pittman; Mineral Resources, Nos. 7 and 8, 1900; The Seven Colonies of Australasia, 1899–1900, by T. A. Coghlan; and by the same author: Forty Years of Progress in, The Fauna of, The Climate of, Agriculture in, The Mining Industry of, and the Timber Resources of New South Wales.

The following Official Publications from the Government of Western Australia:—Supplement to Government Gazette of Western Australia; Department of Mines (Mining Statistics), 1899 and 1900; Statistical Register, Part VII (Mineral Statistics and Water Conservation), 1898 and 1899; Report on the Working of the Government Railways and Tramways for the year ended 30 June 1900; The Mineral Wealth of Western Australia, by A. G. Maitland.

Gold-Fields of Victoria, Monthly Returns; Third Annual Report for year ending 30 June 1901; from the Chamber of Mines, Victoria.

New Zealand, notes on its Geography, Statistics, Land System, Scenery, Sports, and the Maori Race, by R. A. Loughnan; from the Government of New Zealand.

The following from the Government of the United States of America:—Annual Reports of the Chief of Ordnance, 1897–1900; Notes on the Construction of Ordnance; Tests of Metals, &c., at Watertown Arsenal, Massachusetts, 1899 and 1900; Annual Report of the Chief of the Bureau of Steam Engineering, 1900 and 1901.

The following from the U.S. Geological Survey:—Twentieth Annual Report, Parts II, III, IV, V (with Maps) and VII, 1898–99; Twenty-first Annual Report, Parts I, VI and VI continued, 1899–1900; Preliminary Report on the Cape Nome Gold Region, Alaska, 1900; Monographs, XXXIX and XL; Bulletins, 163–176.

PAMPHLETS, &c.

Réceptions des Délégués des Sociétés Techniques et Savantes à l'occasion de l'Exposition de 1900; from the French Society of Civil Engineers.

Elberfeld Electrical Supply Works: Report (Translation) upon the Tests made in January 1900 of a 1,000 kilowatt Steam-turbine and Alternator, by W. H. Lindley, M. Schröter and Dr. H. F. Weber; from Messrs. C. A. Parsons and Co.

History of the Holyhead Railway Boat Service; History of the Holyhead Mail Boat Service; History of the Britannia Tubular Bridge; History of the London and Birmingham Railway; History of the Warrington and Newton Railway; History of the Wigan Branch, and the Preston and Wigan Railway (afterwards the North Union Railway); History of the Pinxton and Leicester (afterwards Midland Counties Railway); History of the Leeds and Bradford and Leeds and Bradford Extension Railways; History of the Birmingham and Gloucester, and Bristol and Gloucester Railways; from the author, Mr. C. E. Stretton.

Account of the Registered Values of Iron and Steel Machinery (exclusive of Sewing Machines and Cycles), Imported into the United Kingdom during 1898, 1899 and 1900; Statement of the Value of Registered Exports of Iron and Steel Machinery (except Cycles and Sewing Machines) of Foreign and Colonial Origin, from the United Kingdom during 1898, 1899 and 1900; from Mr. A. J. Wood.

Royal Commission Paris Exhibition, 1900: List of Awards; from the Royal Commission.

Do American Railways Pay, by D. Car-Skaden; from Mr. J. A. Naugle.

Experiments on the Strength of Building Materials used in Southern India; Hydraulic Experiments in the Kistna Delta; from the author, Prof. Alfred Chatterton.

Le Matériel Moteur des Chemins de fer en l'an 1900, by E. Sauvage; from the author.

The Nomenclature of the Power Loom, by O. S. Hall; from the author.

Report of the Hydraulic Engineer on the Water Supply of Queensland, 1900; from Mr. J. B. Henderson.

Report on the Position and Progress of Artesian Boring in New South Wales, by J. W. Boultbee; from the Hon. E. W. O'Sullivan.

Weitere Fortschritte in der Verwendung der Hochofengase zur unmittelbaren Krafterzeugung, by F. W. Lürmann; from Herr E. Schrödter.

Petroleum in Eastern Europe, and the Method of Drilling for it, by A. W. Eastlake; from the author.

Designing Ironwork, Second Series, Part II, by Prof. Henry Adams; from the author.

An Extension of the Dewey Decimal Classification applied to Mechanical Engineering and Railway Engineering; from Prof. L. P. Breckenridge.

Photographic Surveying; Description of the Bridges-Lee new patent Phototheodolite; from the author, Mr. J. Bridges Lee.

Design, Construction and Cost of Open and Covered Service Reservoirs; Some Statistics dealing with Evaporation, Rainfall and Delivery of Streams in Devonshire; from the author, Mr. William Ingham.

Advantages of the Metric System compared with British Weights and Measures, by F. H. Livens; from the author.

Report on the Conditions and Modes of Working on the Goldfields of Queensland, by William Blane; from the author.

Warming of Buildings by Hot Water, by Ernest King and Kenneth Gray; from Mr. Ernest King.

Mechanical Exhibits in the Glasgow Exhibition, by D. H. Morton; from the author.

Description of the Reduction Plants and Processes of Reduction on some of the principal Kalgoorlie Gold Mines; Illustrated Handbook of Western Australia; from the W. A. Royal Commission.

Evolution of the Locomotive Engine, by W. P. Marshall; from the author.

A New Extensometer, by Prof. Henry T. Bovey; from the author.

On Liquid Air and its application, by John Frick; from the author.

Electro-pneumatic Signalling, by E. de M. Malan; from the author.

Are our Industrial Leaders efficiently trained; from the Association of Technical Institutions.

The Profitable Utilisation of Power from Blast-furnace Gases; The Generation and Transmission of Electric Energy at and from Coal Pit Centres; from the author, Mr. B. H. Thwaite.

Pocket-book of Standards and Tables of Constructional Steelwork; from Mr. B. van Homan.

Report of the National Physical Laboratory Committee of the Royal Society on the Observatory Department, 1900; from the Committee.

List of Chinese Lighthouses, Light-vessels, Buoys and Beacons, 1901; from the Inspector-General of Chinese Customs.

Board of Trade Reports on Boiler Explosions; from the Board of Trade.

Report to the Governors of the City and Guilds of London Institute, March 1901; from the Institute.

Crystal Palace Engineering School Magazine; from Mr. J. W. Wilson.

Sixth Annual Report, 1900, of the John Crerar Library, Chicago; from the Library.

Year-Book of the Royal Society, 1901; Third, Fourth and Fifth Series of Reports to the Malaria Committee, 1900; from the Royal Society of London.

Register of the Institute of Chemistry of Great Britain and Ireland, 1901–1902 from the Institute.

Classified Lists and Distribution Returns of Establishment, Indian Public Works Department, to 31 December 1900 and 30 June 1901; from the Registrar.

Calendars 1901–1902 from the following Colleges:—Royal Technical High School, Berlin; University of Birmingham; Municipal Technical College, Bradford; University College, Bristol (Calendar and Report); Glasgow and West of Scotland Technical College (Calendar and Report); Yorkshire College, Leeds (Calendar and Report); City of London College; King's College, London; McGill College and University, Montreal; Redruth School of Mines; University College, Sheffield; Civil Engineering College, Sibpur.

Electrical Trades' Directory and Handbook, 1901; from the publishers.

Universal Directory of Railway Officials, 1901; from the publishers.

Guide to the Search Department; Key to the Classification of the Patent Specifications of Germany, Austria, Denmark and Norway; Subject List of works on certain Chemical Industries; Ditto of works on Chemical Technology; from the Patent Office.

PHOTOGRAPHS.

Album of Photographs: Traction Engines in the Transvaal War, 1900–1901; from Messrs. John Fowler and Co.

Album and Photographs of the Mechanical Section of the Nijni Novgorod Russian Exhibition, 1895; from Mr. A. W. Fithian.

CATALOGUES.

Boilers for all purposes; from Messrs. Lumby, Son and Wood.

Refrigerating and Ice-making Machinery; from Messrs. J. and E. Hall.

Engines for Electric Lighting, Power and Traction; from Messrs. Belliss and Morcom.

Steam Engines and Condensing Plants; from Messrs. Cole, Marchent and Morley.

Machine Tools; from Messrs. Lee and Hunt.

Hand Tools; from Messrs. Easterbrook, Allcard and Co.

Conveying Plant; from the New Conveyor Co.

Types of Tank Locomotives; from Mr. Thomas Turner.

Railway Safety Appliances: Illustrations of Interlocking Installations; from Mr. Charles Hodgson.

Boring Mills, Turret Machines and Lathes; from the Bullard Machine Tool Co.

Crosby Steam Gage and Valve Co.; The Steam Engine Indicator; and Chapman Valve Manufacturing Co.; from Mr. G. A. Mower.

Inclined Retort System, Edinburgh; from Mr. Maurice Graham.

Steam Gauges and Safety Valves; from Mr. Isaac Smith.

Notes on Foundry Practice; Limit Gauges; from Messrs. L. Loewe and Co.

Scientific Instruments; from the Cambridge Scientific Instrument Co.

The following PUBLICATIONS from the respective Societies and authorities:—

BRITISH ISLES.

Barrow-in-Furness Free Public Library; Eighteenth Annual Report.

British Association for the Advancement of Science; Report.

British Fire Prevention Committee.

Civil Engineers, The Institution of; Proceedings.

Cleveland Institution of Engineers, Middlesbrough; Proceedings.

Cold Storage and Ice Association; Proceedings.

Electrical Engineers, Institution of; Journal.

Engine, Boiler, and Employers' Liability Insurance Company, Manchester; Report (from Mr. Michael Longridge).

Engineers and Shipbuilders in Scotland, Institution of, Glasgow; Transactions.

Incorporated Gas Institute; Transactions.

Ipswich Engineering Society; Transactions.

Iron and Steel Institute; Journal.

Junior Engineers, Institution of; Transactions.

Literary and Philosophical Society of Manchester; Proceedings.

Liverpool Engineering Society; Transactions.

Manchester Association of Engineers; Transactions.

Manchester Geological Society; Transactions.

Manchester Steam Users' Association; Reports.

Marine Engineers, Institute of; Transactions.

Mining Engineers, Institution of, Newcastle-on-Tyne; Transactions.

Naval Architects, Institution of; Transactions.

North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne; Transactions.

North-East Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne; Transactions.

Patent Agents, Chartered Institute of; Transactions.

Philosophical Society of Glasgow; Proceedings.

Physical Society of London; Proceedings.

Radcliffe Library, Oxford; Catalogue of Additions during 1900.

Royal Agricultural Society of England; Journal.

Royal Cornwall Polytechnic Society, Falmouth; Report.

Royal Dublin Society; Transactions and Proceedings.

Royal Engineers' Institute, Chatham; Professional Papers.

Royal Institute of British Architects; Transactions and Journal.

Royal Institution of Great Britain; Proceedings.

Royal Irish Academy, Dublin; Transactions and Proceedings.

Royal Scottish Society of Arts, Edinburgh; Transactions.

Royal Society of London; Philosophical Transactions (A) and Proceedings.
Royal United Service Institution; Journal.
Science Abstracts—Physics and Electrical Engineering.
Society of Arts; Journal.
Society of Chemical Industry; Journal.
Society of Engineers; Transactions.
South Wales Institute of Engineers, Cardiff; Proceedings.
Staffordshire Iron and Steel Institute, Dudley; Proceedings.
Surveyors' Institution; Transactions and Professional Notes.
Waterworks Engineers, British Association of; Transactions.
West of Scotland Iron and Steel Institute, Glasgow; Journal.

Argentine Republic.

Engineers of River Plate, Institution of, Buenos Aires; Journal.

Austria.

Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines, Vienna.
Zprávy spolku Architektův a Inženýrů v království českém, Prague.

Belgium.

Académie Royale de Belgique, Brussels: Bulletin.
Association des Ingénieurs sortis des Écoles spéciales de Gand; Annales.
International Railway Congress (English edition), Brussels; Bulletin.

Canada.

Canadian Society of Civil Engineers, Montreal; Transactions.

France.

Académie des Sciences, Paris; Comptes Rendus des Séances.
Annales des Mines, Paris.
Association Technique Maritime, Paris; Bulletin.
Associations de Propriétaires d'Appareils à Vapeur, Paris; Compte Rendu des Séances.
Conservatoire des Arts et Métiers, Paris; Annales.
Ponts et Chaussées, Paris; Annales.
Revue Maritime, Paris.
Société d'Encouragement pour l'Industrie Nationale, Paris; Bulletin.
Société Industrielle de Mulhouse; Bulletin.
Société Industrielle du Nord de la France, Lille; Bulletin.
Société Industrielle de Rouen; Bulletin.
Société Industrielle de St. Quentin et de l'Aisne, St. Quentin; Bulletin.
Société des Ingénieurs Civils de France, Paris; Mémoires.

Germany.

Zeitschrift für Architektur und Ingenieurwesen, Hannover.
Zeitschrift des Bayerischen Dampfkessel-Revisions-Vereins, Munich.
Zeitschrift des Vereines deutscher Ingenieure, Berlin.

Holland.

Tijdschrift van het Koninklijk Instituut van Ingenieurs, 's Gravenhage.

India.

Asiatic Society of Bengal, Calcutta; Proceedings and Journal.

Italy.

Associazione fra gli Utenti de caldaie a Vapore nelle Provincie Napolitane; Rapporto dell' Ingegnere Direttore.
Collegio degli Ingegneri Navali e Meccanici in Italia, Genoa; Atti.
Società degli Ingegneri e degli Architetti Italiani, Rome; Annali.

Japan.

Japan Society of Mechanical Engineers, Tokyo; Journal.

New South Wales.

Australasian Institute of Mining Engineers, Melbourne; Transactions.
Royal Society of New South Wales, Sydney; Journal and Proceedings.

Norway.

Teknisk Ugeblad, Christiania.

Sweden.

Geological Institution of the University of Upsala; Bulletin.
Svenska Teknologföreningen, Stockholm.

United States.

American Institute of Mining Engineers, New York; Transactions.
American Philosophical Society, Philadelphia; Transactions and Proceedings.
American Society of Civil Engineers, New York; Transactions and Proceedings.
Association of Engineering Societies, Philadelphia; Journal.
Franklin Institute, Philadelphia; Journal.
School of Mines Quarterly, Columbia College, New York.
Smithsonian Institution, Washington; Annual Report.
United States Artillery, Fort Monroe; Journal.
United States Naval Institute, Annapolis; Proceedings.
United States Patent Office Gazette, Washington.
Western Society of Engineers, Chicago; Journal.

The following PERIODICALS from the respective Editors:—

BRITISH ISLES.

Appointments Gazette.
Arms and Explosives.
The Autocar.
Automotor and Horseless Vehicle Journal.
The British Architect.
The British Empire Review (from Mr. Henry Chapman).
British Refrigeration.
The Builder.
Builders' Journal and Architectural Record.
Camera Club Journal.
Cassier's Magazine.
The Chamber of Commerce Journal (from Mr. Henry Chapman).
Cold Storage and Ice Trades Review.
The Colliery Guardian.
The Contract Journal.
The Cyclist.
Domestic Engineering.
The Electrical Engineer.
The Electrical Review.
The Electrician.
The Electro-Chemist and Metallurgist.
The Engineer.
The Engineer and Iron Trades' Advertiser.
Engineering.
The Engineering Magazine.
Engineering Times.
Engineers' Gazette.
Feilden's Magazine.
The Fireman.
The Journal of Gas Lighting.
Hardware, Metals and Machinery.
The Hardware Trade Journal.
Ice and Cold Storage.
Imperial Institute Journal (from Mr. Henry Chapman).
Invention.
Inventors' Review.
The Iron and Coal Trades Review.
Iron Trade Circular, Ryland's.
The Ironmonger.
Lightning.
Locomotive Magazine.
London Technical Education Gazette.
The Machinery Market.
The Marine Engineer.
The Mariner.
The Mechanical Engineer.
Mechanical Progress.
The Mechanical World.
Midland Counties Herald.
The Mining Journal.
Model Engineer and Amateur Electrician.
Motor Car Journal.
Phillips' Monthly Machinery Register.
The Plumber and Decorator.
The Practical Engineer.
Property Gazetteer.
The Public Health Engineer.
The Quarry.
The Railway Engineer.
The Railway Magazine.
The Shipping World.
The Steamship.
The Surveyor.
The Syren and Shipping Illustrated.
The Textile Recorder.
Traction and Transmission.
Trade and Industry.
The Tramway and Railway World.
Transport.
Water.

Belgium.

Revue Universelle des Mines.

France.

L'Industrie.
Revue Industrielle.
Revue générale des Chemins de fer.

Germany.

Glaser's Annalen.
Stahl und Eisen.

Holland.

De Ingenieur.

India.

The Indian and Eastern Engineer.
Railways.
Indian Textile Journal (English edition).

Italy.

Giornale del Genio Civile.

Spain.

El Ingeniero Español (London edition).

United States.

American Machinist.
American Manufacturer.
Architecture (from the B. and S. Folding Gate Co.).
Electrical Review.
Electrical World and Engineer.
Electricity.
The Engineering and Mining Journal.
Engineering News.
The Engineering Record.
The Iron Age (from Mr. W. H. Maw).
Machinery.
Marine Engineering.
Marine Review.
The Railway and Engineering Review.
Railway Master Mechanic.

The President, in moving the adoption of the Annual Report, congratulated the Institution on the excellent work which had been done during the past year, which he characterised as a most successful year in many ways. In the first place, no less than ten Papers had been read, all of great interest, and very thoroughly discussed; and in addition sixteen Papers had been read before the

Congress at Glasgow. To all intents and purposes that Congress formed an additional Summer Meeting of the Institution, and the members would get the full benefit of the Papers read there by their publication in the Proceedings. He thought it would be found that the Papers and discussions at the Congress were fully equal in quality to the Papers discussed in London. The Glasgow meeting was a very successful one, and his only regret was that all the members could not take part in it. The additional Papers read at Glasgow had thrown a very large amount of work on the staff of the Institution, and it was only right that he should say the demands thus made on the staff of the Institution had been met in the very best spirit by everybody connected with it. There had been some very hard work done and done exceedingly well, and he thought that all the members of the staff deserved that public recognition. If any member wished to speak upon the subject of the Report, they would be very glad to hear him.

No remarks being made, the Report was put and unanimously adopted.

The President said his next duty was a very pleasant one, that of presenting the Prizes to three of the Graduates who had read Papers during the past Session. He explained that the Papers read by graduates were referred to a committee of the Council, who read the Papers carefully, and awarded a certain number of marks to each Paper. When the Papers were returned from the various examiners, those points were added up, and the Prizes awarded in accordance with the number of points gained. The Paper which took the largest number of points, and which was therefore accorded the first prize, was that by Mr. W. H. Tregoning on "Tin Plate Manufacture." In the second prize it was found that two of the Papers had gained the same number of points, and the Council therefore took the course which they thought best, that of giving two second prizes of equal value. Those two prizes were given to Mr. H. H. Johnson of Cape Town for a Paper on "Gold Extraction from Free Milling Ore," and to Mr. Alfred Marsden of London for his Paper on "Motor-car Transmission Mechanism."

The President then presented the Prizes to Mr. Tregoning and Mr. Marsden, Mr. Johnson being in Cape Town.

The President announced that the Ballot Lists for the election of Officers for the present year had been opened by a committee of the Council, and that the following were found to be elected:—

PRESIDENT.

William H. Maw,	London.

VICE-PRESIDENTS.

Bryan Donkin,	London.
Edward P. Martin,	Dowlais.

MEMBERS OF COUNCIL.

Henry Davey,	London.
Sir William T. Lewis, Bart.,	Aberdare.
The Right Hon. William J. Pirrie, LL.D.,	Belfast.
Sir Thomas Richardson,	Hartlepool.
Mark H. Robinson,	Rugby.

The Council consists therefore of the following:—

PRESIDENT.

William H. Maw,	London.

PAST-PRESIDENTS.

Sir Lowthian Bell, Bart., LL.D., F.R.S.,	Northallerton.
Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S.,	London.
Sir Edward H. Carbutt, Bart.,	London.
Samuel Waite Johnson,	Derby.

Prof. Alexander B. W. Kennedy, LL.D., F.R.S.,	London.
E. Windsor Richards,	Caerleon.
John Robinson,	Leek.
Percy G. B. Westmacott,	Ascot.
Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.,	London.

VICE-PRESIDENTS.

John A. F. Aspinall,	Manchester.
Bryan Donkin,	London.
Arthur Keen,	Birmingham.
Edward P. Martin,	Dowlais.
T. Hurry Riches,	Cardiff.
J. Hartley Wicksteed,	Leeds.

MEMBERS OF COUNCIL.

Sir Benjamin Baker, K.C.M.G., LL.D., D.Sc., F.R.S.,	London.
Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S.,	London.
Henry Chapman,	London.
Henry Davey,	London.
William Dean,	Swindon.
H. Graham Harris,	London.
Henry A. Ivatt,	Doncaster.
Sir William T. Lewis, Bart.,	Aberdare.
Henry D. Marshall,	Gainsborough.
The Right Hon. William J. Pirrie, LL.D.,	Belfast.
Samuel R. Platt,	Oldham.
Sir Thomas Richardson,	Hartlepool.
Mark H. Robinson,	Rugby.
A. Tannett-Walker,	Leeds.
John I. Thornycroft, LL.D., F.R.S.,	London.

The PRESIDENT thanked the Members very heartily for having done him the honour of re-electing him President for the coming year. He assured them it was an honour he appreciated most thoroughly, and he hoped that he might be able to carry out the duties of the office in a way that would justify the selection.

The PRESIDENT reminded the Members that at the present Meeting the appointment had to be made of an Auditor for the current year.

Mr. C. E. STROMEYER moved:—"That Mr. Robert A. McLean, F.C.A., of 1 Queen Victoria Street, London, E.C., be re-appointed to audit the accounts of the Institution for the present year, at the same remuneration as last year, namely, Twenty-five Guineas."

Mr. HENRY M. ROUNTHWAITE seconded the motion, which was carried unanimously.

SPECIAL MEETING.

The Meeting was then made a Special Meeting to consider the alteration of Article 23.

The President pointed out that Members and Associate Members only were entitled to vote. He did not think there was any necessity for asking any visitor or anyone not belonging to these classes of membership to retire. The matter to be considered had been mentioned at the previous meeting. The Council had had under consideration the desirability of increasing the number of ordinary Members of Council. At present the Council consisted, apart from Past-Presidents, of the President, six Vice-Presidents, and fifteen ordinary Members of Council. No doubt in the old days when there were only four meetings a year, and when the business to be done was very much less than it was now, that number of Members of Council was ample; but with the increasing number of meetings, committees, and other work, the present arrangement made heavy demands on the Council's time. It was therefore desirable to increase the number, in order to be sure of always obtaining a quorum.

There was another matter. Besides transacting the ordinary executive business of the Institution, a task which fell more or less strongly on the London Members of Council, it was desirable that the Council should represent the various districts of the country and the various branches of work to which the Institution had reference. In order to secure adequate attendance at the Committee Meetings of the Institution and the frequent Council Meetings, it was necessary to have a very large proportion of London Members. At the present time there was no representative for Scotland or for such a large town as Manchester (although Lancashire was represented), and there were other large towns of which no representative sat on the Council. It was impossible to reduce the number of London members to supply those gaps, and for that reason the Council desired to increase the number of ordinary members from fifteen to twenty-one. In order to carry that out, it would be necessary to pass an alteration to Article 23 of the Articles of Association of the Institution. That Article at present provided for the election of fifteen members of Council, and he moved that Article 23 be altered as follows:—

> "Article 23.—The Council of the Institution shall be chosen from the Members only, and shall consist of one President, six Vice-Presidents, twenty-one ordinary Members of Council, and of the Past-Presidents. The President, two Vice-Presidents, and seven Members of Council (other than Past-Presidents), shall retire at each Annual General Meeting, but shall be eligible for re-election. The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by Ballot."

At present five retired, and with the increased number of the Council seven would retire.

Mr. J. HARTLEY WICKSTEED, Vice-President, seconded the proposition, and said that the whole Council were of one opinion about it. They all thought it would be a very good thing to increase the number of Members of Council for the reasons that had been given by the President.

Mr. CHARLES HAWKSLEY moved as an amendment that the word "otherwise" be inserted after the word "agree," making that part of the Article read "The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree otherwise amongst themselves, be chosen from those who have been longest in office, and in case of equal seniority shall be determined by ballot."

Mr. E. H. G. BREWSTER seconded the amendment, which was unanimously agreed to.

The PRESIDENT then moved the amended Article as a substantive resolution.

Mr. E. J. **Chambers** supported the resolution. He was quite sure that the gentlemen who formed the Council, and who had ruled the Institution for many years past, would rejoice to think that their labours were to be at least lightened, and their responsibility shared by an increased number. He had felt for some time that the Institution had more to do than to read and discuss mechanical Papers. There were many subjects which interested the mechanical world very much all over the country. They were coming to the front very strongly at the present time; and therefore the more fresh blood brought into the Council from all parts of the kingdom to represent the various phases of thought existing in those various parts, the better. It would then be found that the Council not only represented the feeling of the members, but that it would find time to take part in the development of those important questions. He had had once or twice the honour of speaking at the Institution, and of suggesting that beyond the discussion on Papers it was the duty of the Institution to watch over very carefully the mechanical development of mechanical engineering in this country. He trusted that when the number of the Council was increased, as was now suggested—and he hoped the members would unanimously carry the proposition—there would be sub-committees of the Council formed for the purpose of watching over the interests of mechanical engineering in this country, and of seeing that the members were kept well informed as to the best lines on which they could proceed to keep up the prestige, which had attained such a high eminence in spite of all competition. Not only did he desire that prestige kept up, but increased. That could be materially assisted by the increase in the number of Members on the Council.

Mr. C. E. **Stromeyer** assured the Institution that the proposal was welcomed in the country, especially in Manchester. Manchester was looked upon by Manchester engineers as the metropolis of mechanical engineering. He was very pleased to see the provinces were to be represented more than they had been, without reducing the number of London members.

The resolution was then put and unanimously agreed to.

The President then pointed out that it would be necessary to have a Special Meeting of the Institution to confirm the Resolution, and it was proposed to hold that Meeting on Monday, 10 March, at 5.30 p.m.

The Special Business having been completed, the discussion was resumed and concluded on Mr. Orcutt's Paper on "Modern Machine Methods."

The reading and discussion of the four Papers on the "Fencing of different kinds of Machinery" was deferred to the next Ordinary General Meeting.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 114 Members and 61 Visitors.

TRIAL OF A TRIPLE-EXPANSION VERTICAL CONDENSING STEAM-ENGINE FOR HYDRAULIC PUMPING.

(With Steam slightly superheated.)

By Mr. CHARLES J. HOBBS, *Member*, of London.

The following particulars and figures are submitted by the author in connection with some trials, which were made by him in 1901, on a Triple-Expansion Vertical Hydraulic Pumping-Engine working at the Millbank (new extension) Pumping Station of the London Hydraulic Power Co. The immediate object of the trials was to ascertain for the information of Messrs. Ellington and Woodall, the engineers to the company, if the engine (one of four) came up to the requirements of the contract as to its feed consumption; but it was decided to take further observations to make the trials complete, and to see how the results obtained compared with some of the best results which have been obtained and published from time to time from modern first-class pumping machinery.

With reference to hydraulic pumping machinery and engines used for the purpose of lifting water against an accumulator, it has been observed by the author that there seems to be a peculiar tendency not to consider so much the importance of the steam and coal consumption, so long as the plant is sufficiently large and powerful enough to get the requisite amount of pressure water through the hydraulic mains to meet the requirements of the machines at the other end. At the present time it is very usual to see engines of large size being put down without any condensing apparatus, and very often with both cylinders of the same diameter.

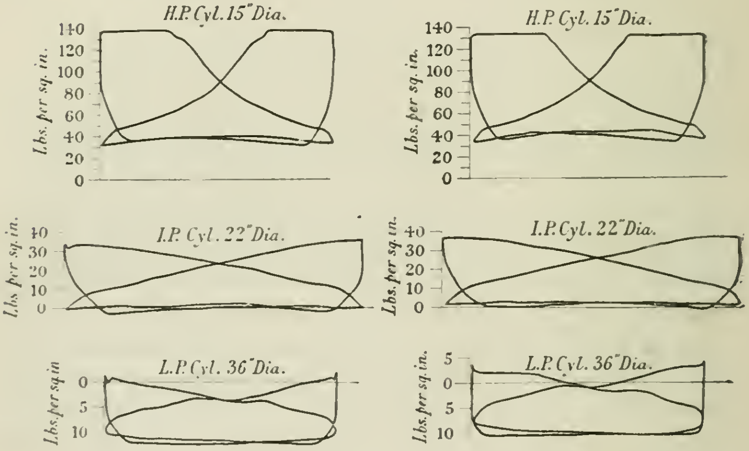
This is said to be partly due to the peculiarities of the service and the intermittent nature of the work; but there is no reason, in the author's opinion, why more attention should not be paid to economy and to the advantage of putting down machinery designed on less antiquated lines, even if the initial cost may be somewhat greater.

Description of the Engine.—The engine, Fig. 2 (page 171), was constructed by the Hydraulic Engineering Co., Chester, for the London Hydraulic Power Co.'s new pumping station at Millbank, and is generally similar to one tested at Wapping by the late Mr. Bryan Donkin during the trials conducted by the Research Committee on the Value of the Steam-Jacket.* Some typical indicator diagrams are shown in Fig 1. It is of "Ellington's" triple-expansion vertical marine type, having jacketed cylinders, 15 inches, 22 inches, and 36 inches diameter each, with a stroke of 24 inches, and the low-pressure cylinder cover is also jacketed; fitted with surface condenser,

FIG. 1.—*Indicator Diagrams.*

Trial No. 1.
3rd April 1901.

Trial No. 2.
4th April 1901.



---

* Proceedings, 1894, page 536.

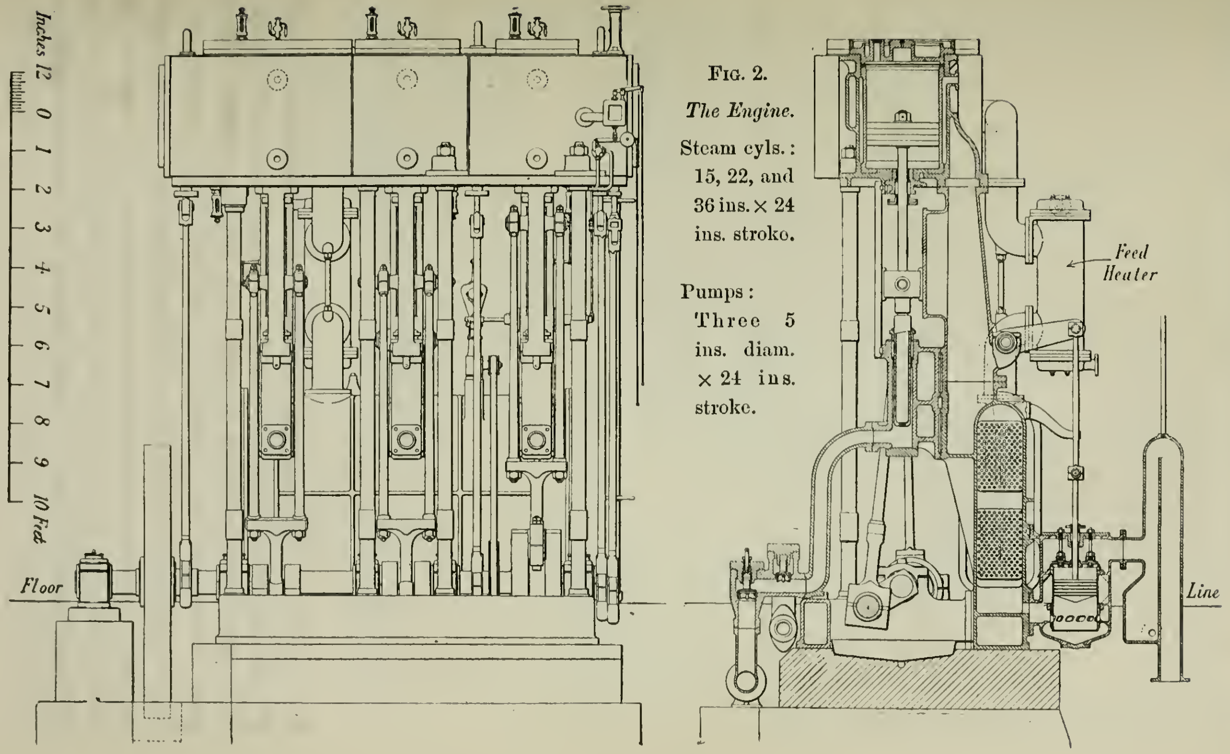


FIG. 2.

The Engine.

Steam cyls.: 15, 22, and 36 ins. × 24 ins. stroke.

Pumps: Three 5 ins. diam. × 24 ins. stroke.

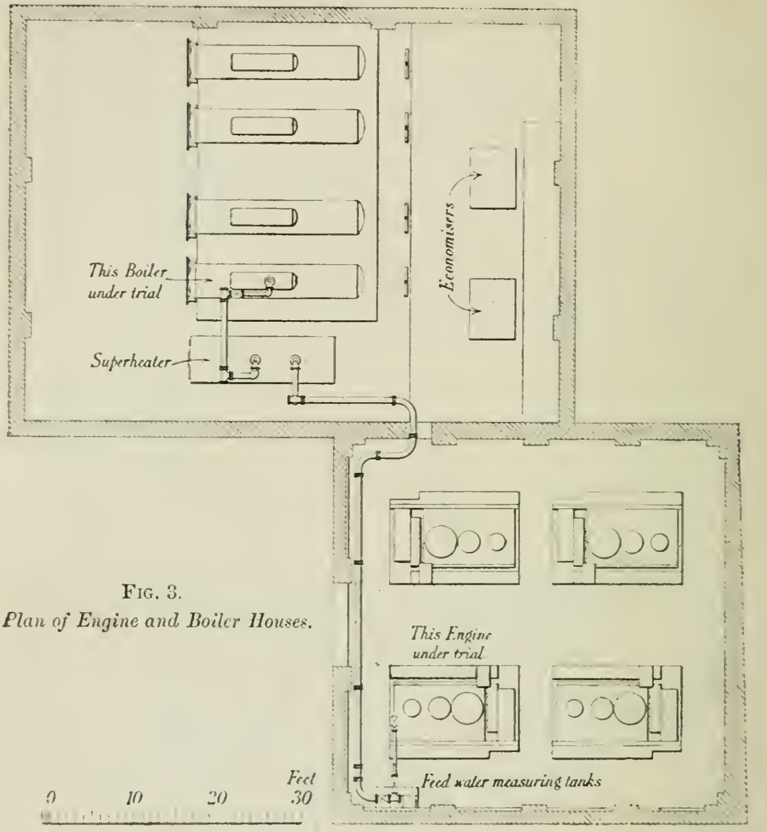
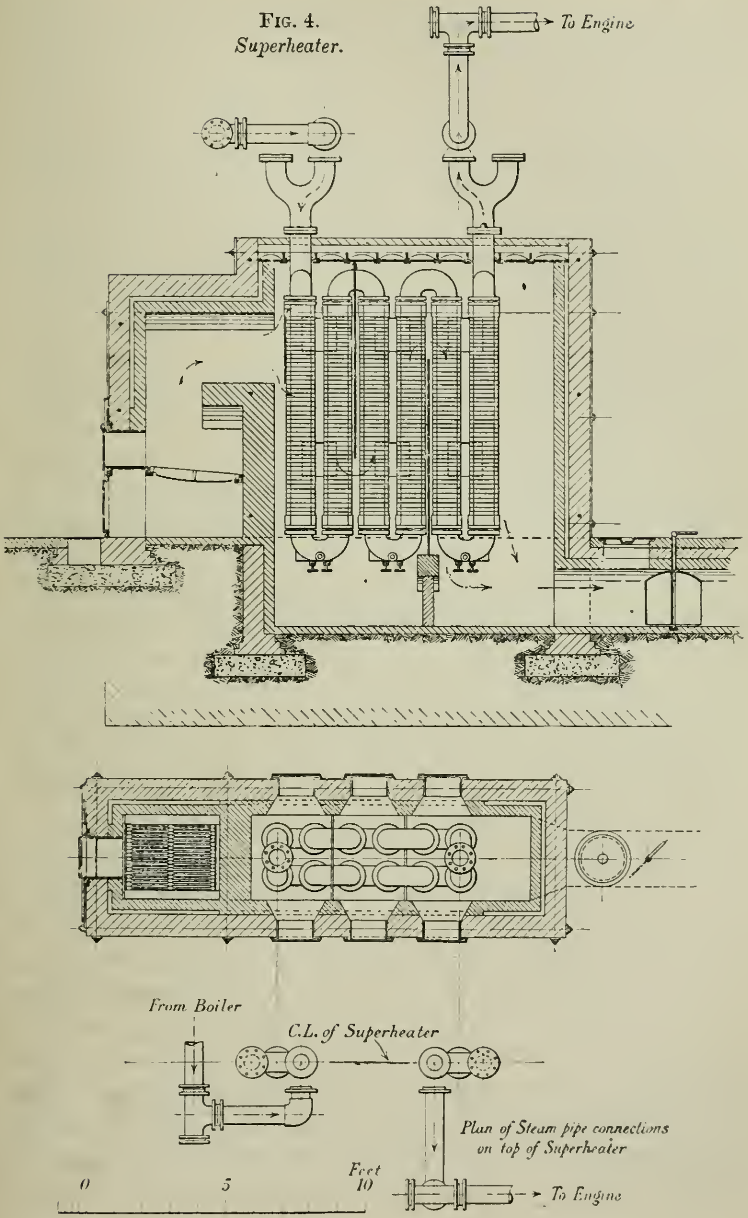


Fig. 3.
Plan of Engine and Boiler Houses.

the air-pumps (Edwards), Fig. 2, and feed and circulating pumps are actuated by levers from the crosshead of the intermediate cylinder. The high-pressure cylinder is fitted with Meyer's variable cut-off plates working on an ordinary D slide-valve, and the intermediate and low-pressure cylinders have D slide-valves only. The water for condensing purposes circulates through the tubes, and is returned by the circulating pumps to overhead tanks, the exhaust steam passing on the outside of the tubes. In accordance with a suggestion made by Mr. Ellington, the exhaust steam on its way to the condenser is

FIG. 4.
Superheater.



made to pass through a feed-heater, which was found to give very satisfactory results, and raised the temperature of the feed-water between 20° and 30° F.

Water Pumps.—These are three in number and worked direct off the piston-rods below the cylinders, having plungers 5 inches diameter. At a short trial of 3 hours on 10th April 1901, the pumps were tested for discharge at a speed of 60·7 revolutions per minute, and gave 4·97 gallons per revolution. The double-acting circulating pump is 8 inches diameter with a stroke of 16 inches. There was unfortunately no convenience at this station for measuring the actual discharge from this pump, but previous to the trial all the valves, etc., were carefully examined and the discharge was taken as being 5·075 gallons per revolution, which was the result obtained from a similar engine at Wapping, when the circulating water was measured for 9 hours continually at approximately the same speed.

Boiler.—The boiler used during the trials was one of a set of four, Fig. 3 (page 172), and is of the Fairbairn-Beeley type made by Messrs. Beeley, Hyde, Manchester. It consists of the usual two shells, one above the other, peculiar to this type, the lower one, 5 feet diameter by 18 feet long, containing the fire tube 3 feet 9 inches diameter, and 65 combustion tubes, 3 inches outside diameter and 4 feet 10½ inches long. It is connected to the upper shell by three circulating water-tubes, and the water-level is maintained at the centre of the upper shell. The total heating surface of the boiler is 1033·64 square feet and the grate area 20 square feet. In connection with same, there is a Green's economiser provided with 192 pipes, giving a heating surface of 2,062 square feet, or a total heating surface with the boiler of 3,095·64 square feet. The temperature of the feed water, after passing through the tubes, gradually rose (for the first trial) from a temperature of 240° F. at the commencement of the trial to 287° F., which was the last reading (average for 10 hours 270·45° F.), and for the second trial from 225° F. to 258° F. (average for 6 hours, 244° F.). The boiler is also provided with a Vicars' Mechanical Stoker.

Superheater.—The steam on leaving the boiler in the first trial was passed through a Schwoerer superheater, Fig. 4 (page 173), made by Messrs. Fraser and Chalmers. It is fitted with a separate furnace and fed with coke, and the intention during the trial was as nearly as possible so to arrange the temperature of the steam issuing from the superheater as to give perfectly dry steam to the engine, without to any appreciable extent raising the temperature of the steam at the engine, beyond what was due to its pressure at that point. Thus in the trial with the pressure at the engine of 151·7 lbs. absolute, the temperature was 362·75° F., giving 3·45° of superheat. In taking into consideration the results obtained with the superheater, it must be remembered that it is intended to deal with the steam for three or four engines working at the same time, and the size of steam main is calculated on the same lines. There was a great loss of superheat between the superheater and the engine, due to the length and size of the steam pipe in proportion to the quantity of steam used for only one engine, and it will be noted that the gross quantity of fuel used in boiler and superheater together in the first trial was greater than that used in the second trial when the superheater was out of use, although in the first trial the steam consumption was some 9 per cent. better than when using the ordinary saturated steam. In the first trial it is evident that the full advantage from the fuel was not being obtained in the superheater, but was probably assisting the evaporation in the boiler by raising the temperature of the feed-water through the economiser, around the tubes of which the gases from the superheater flowed on their way to the uptake. The amount of superheat at the superheater rose from a temperature of 355° F. at the commencement of the trial to 456° F. which was the last reading, but at times the thermometer recorded 470° F.; the mean temperature of all the readings (taken every 15 minutes) was 452·5° F.

Coal.—The coal used during the trials was "Durham Rough" small of good quality, and is the usual coal used at the pumping station. It was weighed out in quantities of 2 cwts., and placed in sacks which were numbered and used as required. The level of the coal in the hoppers supplying the mechanical stokers was kept the same at the finish as at the commencement of the trials, and maintained the same throughout. The coke to the superheater in the first trial was weighed out in quantities of 56 lbs.

In taking into consideration the fuel results in the boiler, either with or without the superheater, it must be remembered that the object of the trials was chiefly to ascertain the steam consumption in the engine; and there was no intention of making a complete test of the boiler efficiency, neither were the arrangements of the trial such as to obtain the best economy from the superheater.

The readings of the gauges, thermometers, counter, &c., were taken every fifteen minutes and indicator diagrams every thirty minutes. The figures given in the summary of observations are the means of the same.

Feed-measuring Tanks.—All the steam used in the cylinders during the trials was measured as air-pump discharge from the surface-condenser in two separate tanks, each of a capacity of 100 gallons. Each tank was provided with a vertical rod, pointer and float working up against a scale graduated from 0 to 100 gallons. Above the feed-measuring tanks there were three smaller tanks, each holding 20 gallons. Two were used for taking the condensed water collected in a steam-trap from the jackets; the third was for any auxiliary feed-water required. The quantities of feed-water in the two feed-measuring tanks were checked by two observers. The total quantity of water which was pumped into the boiler consisted of air-pump discharge, jacket-drain discharge, and auxiliary feed to maintain the height of water in the boiler. To obviate the danger of any jacket-drain or auxiliary water (which was measured separately in the 20-gallon tanks) being pumped into the boiler without being recorded in the feed-measuring tanks, these 20-gallon tanks were in every case emptied into the measuring tanks whilst they were being filled from the air-pump discharge, and in no case when they were being emptied, so that no correction had to be made to the amounts recorded on the log sheets, and the addition of all the amounts recorded gave the gross feed. The number of 20-gallon tanks, containing either jacket-drain water or auxiliary feed, were noted separately upon another sheet, and the subtraction of their contents from the gross feed gives the air-pump discharge, or steam passing through the cylinders, and this quantity added to the jacket-water gives the steam passing through the engine.

Contract Requirements.—The contract required that the engine should pump 250 gallons per minute against the accumulator pressure (which varies from 750 to 800 lbs. per square inch), and that the weight of steam passing through the engine should not exceed 15 lbs. per I.H.P., or 18 lbs. per pump H.P. per hour.

From the observations and the different temperatures recorded above, a heat balance sheet has been made out for each trial; and the following symbols are used:—

H_t = Total heat of steam at temperature of inlet steam.
T_s = Degrees of superheat above steam temperature.
L = Latent heat of steam at temperature of inlet steam.
f = Temperature of A.P.D. (air-pump discharge).
i = Rise of temperature of circulating water.
f_h = Rise of temperature of feed water passing through heater on exhaust pipe.
H_h = Heat required to raise water from 32° F. to boiling point.

In the first trial with superheated steam the temperature of the inlet steam was $359 \cdot 3° + 3 \cdot 45°$ superheat.

$f = 70 \cdot 07°$ F.
$f_h = 29 \cdot 9°$ F.
$i = 10 \cdot 9°$ F.
I.H.P. = 192·64.

In the second trial the inlet steam was 355° F.

$f = 73 \cdot 4°$ F.
$f = 21°$ F.
$i = 12 \cdot 2°$ F.
I.H.P. = 194·66.

1st Trial.

Dr.	B.T.U.	*Cr.*	B.T.U.
Heat through Cylinders—		Converted into work—	
$36{\cdot}68\,[H_t + (T_s \times {\cdot}48)]$ =	43816	(I.H.P. × 42·4) =	8167·93
Heat through Jackets—		Carried away in A.P.D.—	
$4{\cdot}4\,[H_t + (T_s \times {\cdot}48)]$ =	5254	$36{\cdot}68 \times (f - 32)$ =	1395·41
		Carried away in Heater—	
		$49{\cdot}75 \times f_h$ =	1487·52
		Carried away in Jacket water—	
		$4{\cdot}4 \times H_h$ =	1452·00
		Carried away in Circulating water—	
		$3093{\cdot}92 \times i$ =	33723·72
		Radiation and Difference =	2843·42
	49070		49070·00

It will be noted from the above figures that the total heat received was utilized as follows:—

Heat expended in work (per cent.)	16·65
,, ,, in A.P.D.	2·85
,, ,, in Heater	3·03
,, ,, in Jacket water	2·96
,, ,, in Circulating water	68·75
Radiation, losses, etc.	5·76
	100·00

2nd Trial.

Dr.	B.T.U.	*Cr*	B.T.U.
Heat through Cylinders—		Converted into work—	
$38{\cdot}58 \times H_t$ =	45910	I.H.P. × 42·4 =	8253·58
Heat through Jackets—		Carried away in A.P.D.—	
$6{\cdot}66 \times H_h$ =	7925	$38{\cdot}58 \times (f - 32)$ =	1597·21
		Carried away in Heater—	
		$52{\cdot}61 \times f_h$ =	1104·81
		Carried away in Jackets—	
		$6{\cdot}66 \times H_h$ =	2171·16
		Carried away in Circulating water—	
		$3162 \times i$ =	38576·40
		Radiation and Difference =	2131·84
	53835·0		53835·00

and the total heat received was utilized as follows:—

Heat expended in work (per cent.)	15·32
,, ,, in A.P.D.	2·96
,, ,, in Heater	2·05
,, ,, in Jackets	4·04
,, ,, in Circulating water	71·62
Radiation, losses, etc.	4·01
	100·00

The above percentage for "Heat expended in work" must not be confused with Thermal Efficiency, as, in the figures above, it is assumed that the heat expended in A.P.D., Heater, and Jackets is wasted, whereas in actual practice it is returned to the boiler. The actual Thermal Efficiency of the engine in ordinary work is given on page 182 as 17·9 per cent. in the first trial and 16·5 per cent. in the second.

*The Thermal Efficiency, or the ratio between the heat utilized as work on the piston compared with the total heat supplied to the engine, is now given for each trial, and from that is calculated the Efficiency Ratio of the engine under test compared with an ideal steam-engine working on the Rankine Cycle between the same temperature and pressure limits. The thermal economy of the engine under test and of an ideal engine is also given in terms of the Thermal Units required per minute per indicated horse-power—

1st Trial.

The following data are taken from the summary of results:—

Indicated Horse-Power		192·64
Pressure of steam at engine (absolute)		151·7 lbs.
Temperature of ditto at valve-chest		362·75° F.
Degrees of superheat		3·45°
Temperature of exhaust (t_e)		141·6°
Quantity of steam per min. through engine	Cylinders	36·68 lbs.
	Jackets	4·4 lbs.

---

* Proceedings, The Institution of Civil Engineers, vol. cxxxiv, pages 278–312.

and give results as follow below; and by the heat returnable it is assumed that the feed is heated to the temperature of the exhaust steam.

	B.T.U.	B.T.U
Total heat of 36·68 lbs. of steam passing through cylinders .	43816	
Less heat returnable in the feed from the exhaust (4·4 + 36·68) × (t_e – 32)	4506	
		39310
Total heat of 4·4 lbs. of steam passing through Jackets .	5254	
		5254
Net heat supply per minute B.T.U.		44564

B.T.U. per I.H.P. per minute $\frac{44564}{192 \cdot 64} = 231 \cdot 3$

Thermal Efficiency $\frac{42 \cdot 4}{231 \cdot 3} = \cdot 183$, or 18·3 per cent.

Taking the formula for the Thermal Efficiency of the Rankine Cycle for superheated steam

$$^{*}\frac{(T_a - T_e)\left(1 + \frac{L_a}{T_a}\right) + \cdot 48\,(T_{as} - T_a) - T_e\left(hyp\,log\,\frac{T_a}{T_e} + \cdot 48\,hyp\,log\,\frac{T_{as}}{T_e}\right)}{L_a + T_a - T_e + \cdot 48\,(T_{as} - T_a)}$$

where

T_a is the absolute temperature of steam at engine.
T_{as} ,, ,, ,, ,, ,, superheated steam.
T_e ,, ,, ,, ,, ,, steam in exhaust.
L_a is the latent heat of steam at temperature T_a.

the Thermal Efficiency of the ideal engine = ·242, or 24·2 per cent.

B.T.U. per H.P. per minute $\frac{42 \cdot 4}{\cdot 242} = 175 \cdot 2$

and the Efficiency Ratio $\frac{175 \cdot 2}{231 \cdot 3} = \cdot 757$.

2nd Trial.

The following data are taken.

Indicated Horse-Power	194·66
Pressure of steam at engine (absolute)	151 lbs.
Temperature of steam at valve-chest	355° F.
Temperature of the exhaust (t_e)	153° ,,

---

* Proceedings, The Institution of Civil Engineers, vol. cxxxiv, page 294.

Total quantity of steam through engine per minute	Cylinders .	38·58 lbs.
	Jackets .	6·6 ,,

which give as results :—

	B.T.U.	B.T.U.
Total heat through cylinders	45910	
Less heat returnable $(t_e - 32) \times (38\cdot58 + 6\cdot66)$ . .	5473	
		40437
Total heat through Jackets	7925	
		7925
Net heat supply per minute B.T.U.		48362

B.T.U. per I.H.P. per minute $\frac{48362}{194\cdot66} = 248\cdot6$

Thermal Efficiency $\frac{42\cdot4}{248\cdot6} = \cdot1705$, or 17·05 per cent.

[*]Taking the formula for saturated steam

$$\frac{(T_a - T_e)\left(1 + \frac{L_a}{T_a}\right) - T_e \, hyp \, log \, \frac{T_a}{T_e}}{L_a + T_a - T_e}$$

the Thermal Efficiency of the ideal engine = ·225, or 22·5 per cent.

B.T.U. per H.P. per minute $\frac{42\cdot4}{\cdot225} = 188\cdot4$

and the Efficiency Ratio $\frac{188\cdot4}{248\cdot6} = \cdot758$.

These figures compare very favourably with results worked out on the same lines for engines which have given good economy,[†] and for the sake of comparison, as recommended in the Report of the Committee on the Thermal Efficiency of Steam-Engines, the author has assumed that the feed-water returned to the boilers was heated to the temperature of the exhaust. In actual practice the temperature of the hot well, or, in the engine under test, that due to the feed heater on the exhaust, would be taken. Making the substitution in the first trial, when the feed-water was raised to 101·9° F., and allowing for the heat taken from the heater by the extra quantity of make-up water to the boilers—

---

[*] Proceedings, The Institution of Civil Engineers, vol. cxxxiv, page 294.

[†] *Ibid*, page 304.

	B.T.U.	B.T.U.
Heat through cylinders	43816	
Less heat returned	2567·6	
		41248·4
Heat through Jackets	5254	
Less heat returned	308	
		4946
		46194·4
Less heat used in raising 8·67 lbs. per minute of make-up water to 101·9° F.		606
Net heat supply per minute B.T.U.		45588·4

B.T.U. per I.H.P. per minute $\frac{45588\cdot4}{192\cdot64} = 236\cdot8$

Thermal Efficiency $\frac{42\cdot4}{236\cdot8} = \cdot179$, or 17·9 per cent.

Efficiency Ratio $\frac{175\cdot2}{236\cdot8} = \cdot74$.

In the 2nd trial $t_e = 104°$ F.

	B.T.U.	B.T.U.
Heat through cylinders	45910	
Less heat returned	2777·75	
		43132·25
Heat through Jackets	7925	
Less heat returned	475·2	
		7449·8
		50582·05
Less heat used in raising 7·37 lbs. per minute of make-up water to 104° F.		530·65
Net heat supply per minute B.T.U.		50051·4

B.T.U. per I.H.P. per minute = 256·5

Thermal Efficiency $\frac{42\cdot4}{256\cdot5} = \cdot165$, or 16·5 per cent.

Efficiency Ratio $\frac{188\cdot44}{256\cdot5} = \cdot735$.

Throughout the trials the engines and pumps were engaged in doing the usual work of the station, the only difference to the ordinary routine being that the other engines of the station were occasionally controlled to allow the engine under test to maintain as constant a speed as possible. For the purposes of the trials ten assistants were employed, and in conclusion the author tenders his best thanks to Mr. E. B. Ellington for many useful suggestions in the arrangements of the trials, and to Mr. George Cochrane, the superintendent of the Power Company, for the facilities afforded in carrying out same.

[Summary of Observations.

SUMMARY OF OBSERVATIONS.*

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

ENGINE. Sheet I. GENERAL DESCRIPTION AND DIMENSIONS.

Type of Engine . . . *Vertical Triple Expansion Condensing* made by *Hydraulic Engineering Co., Chester.*

Maker's rating of the power. *148* Pump Horse Power at *210* feet per minute and *150* lbs. per sq. inch boiler pressure.

Tests made at *165 and 167* P.H.P.

Character of load. *Pumping against accumulator.*

Object of trial. *To ascertain steam consumption.*

General description of Engine.—*3-cylinder vertical engine, 3 cranks at 120° apart, high-pressure crank leading; fly-wheel about 2 tons weight, 7 feet diameter, outside engine frame with a bearing on each side; air-pump driven by lever from intermediate cylinder crosshead, also feed and circulating pumps. Main pumps driven direct below each cylinder. All cylinders jacketed.*

Type of Valves.—*Ordinary* D *slide-valves. Expansion to high-pressure cylinder controlled by Meyer's cut-off valves adjustable by hand.*

How governed.—*By cut-off valve on high-pressure cylinder. Also by high-speed governor actuating a throttle valve, but this was not in use during the trial.*

Particulars of cylinders—

		H.P.	I.P.	L.P.
Diameter of cylinders	inches.	*15·0*	*22·0*	*36·0*
„ „ piston rods	„	*3·0*	*3·0*	*3·0*
Stroke of pistons	„	*24·0*	*24·0*	*24·0*
Volume swept by piston per revolution	c. feet.	*4·8*	*10·5*	*28·2*
Clearance volumes per revolution (mean of two ends) . . .	per cent.	*12·32*	*7·95*	*6·31*
Clearance surfaces	sq. feet.	*11·6*	*16·4*	*31·5*

Particulars of Main Pumps—

Diameter of plungers (3) . . .	inches	5
Stroke of plungers	„	24

---

* Since the trials were made, the results have been arranged in this form on the recommendation of the late Mr. Bryan Donkin.

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

ENGINE. Sheet II. DATA DEDUCED FROM OBSERVATIONS.

		1st trial	2nd trial
Duration of trial		10 hours.	6 hours.
Steam.			
Including jacket water. Weight entering engine cylinders per hour	lbs.	*2465*	*2715*
Steam passing through jackets per hour	lbs.	*264*	*400*
Pressure by gauge at boiler side of stop valve	lbs. per sq. inch.	*137*	*136·3*
Pressure absolute at boiler side of stop valve	„ „ „	*151·7*	*151·0*
Temperature of steam in high-pressure valve-chest	F.	*362·75°*	*355°*
Drainage from jackets per hour	lbs.	*264*	*400*
Jackets per cent. of steam through engine	per cent.	*10·7*	*14·18*
Exhaust Steam.			
Barometric pressure (atmosphere)	inches of mercury.	*29·7*	*29·65*
„ „	lbs. per sq. inch.	*14·51*	*14·49*
Vacuum in condenser	inches of mercury.	*27·2*	*27·17*
Pressure (abs.) in condenser	lbs. per sq. inch.	*1·24*	*1·239*
„ „ at exit from engine	„ „ „	*3*	*3·59*
Temperature at exit from engine	F.	*141·6°*	*153°*
Power.			
Mean effective pressure in H.P. cylinder	lbs. per sq. inch.	*53·8*	*49·47*
„ „ „ „ I.P. „	„ „ „	*21·11*	*20·86*
„ „ „ „ L.P. „	„ „ „	*8·71*	*9·25*
Mean pressure referred to L.P. cylinder	„ „ „	*25·71*	*25·42*
Indicated horse-power	H.P. Cylinder.	*68·83*	*64·52*
„ „ „	I.P. „	*58·57*	*59·33*
„ „ „	L.P. „	*65·24*	*70·81*
Total indicated horse-power		*192·64*	*194·66*
Mean area of L.P. cylinder	sq. inches.	*1014·4*	
Revolutions (by counter)	per min.	*60·94*	*62·28*
Piston speed in feet per minute	per min.	*243·76*	*249·12*
Pump horse-power. *Gallons pumped per minute. 1st trial, 302 gals. 2nd trial, 309 „*		*165·2*	*167·87*

		1st trial 10 hours.	2nd trial 6 hours.
Mechanical efficiency $\frac{\text{P.H.P.}}{\text{I.H.P.}}$		85·8	86·3
Pressure in the accumulator	lbs.	765	761
Gallons pumped per cwt. of coal		5030	5800

Trial of a Steam Plant at *Millbank*. Made on *3rd April, 1901*.

ENGINE. SHEET III. HEAT ACCOUNT AND DEDUCTIONS.

		Heat Balance. In. B.T.U.	Heat Balance. Out. B.T.U.
Gross heat supply entering engine	per minute.	49,070	
Heat equivalent of I.H.P.			8167·93
„ carried away in air-pump discharge			1395·41
„ „ „ „ heater			1487·52
„ „ „ „ jackets			1452·00
„ „ „ „ circulating water			33723·72
Radiation, losses, etc., by difference			2843·42
Heat supplied per minute per I.H.P.	net B.T.U.		231·3
„ „ „ „ „ P.H.P.	„ „		270·01
Heat theoretically required per minute by the "Institution of Civil Engineers standard of comparison" per I.H.P. (Rankine's Cycle)	„ „		175·2
Efficiency ratio		0·757	
Thermodynamic efficiency		0·183	
Pounds of steam used per I.H.P. per hour	lbs.		12·80

Trial of a Steam Plant at *Millbank*. Made on *4th April, 1901.*

ENGINE. SHEET III. HEAT ACCOUNT AND DEDUCTIONS.

		Heat Balance. In. B.T.U.	Heat Balance. Out. B.T.U.
Gross heat entering engine	per minute.	*53,835*	
Heat equivalent of I.H.P.			*8253·58*
„ carried away in A.P.D. . . .			*1597·21*
„ „ „ „ heater . . .			*1104·81*
„ „ „ „ jackets . . .			*2171·16*
„ „ „ „ circulating water .			*38576·40*
Radiation, etc. (by difference) . . .			*2131·84*
Heat supplied per minute per I.H.P. . .	net B.T.U.		*248·6*
„ „ „ „ „ P.H.P. . .	„ „		*288·26*
Heat theoretically required, etc. . . .			*188·4*
Efficiency ratio		*0·758*	
Thermodynamic efficiency		*0·1705*	
Pounds of steam used per I.H.P. per hour .	lbs.		*13·98*

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

ENGINE ACCESSORIES. SHEET I. GENERAL DESCRIPTION AND DIMENSIONS.

CONDENSER.

General description of Condenser.—*Surface condenser; water for condensing purposes circulates through the tubes; exhaust steam passes on outside of tubes.*

FOR SURFACE CONDENSER.

Number of tubes		*356*
Diameter of tubes (*external*)	inches.	*¾*
Length of tubes	ft. ins.	*6 10*
Effective area of cooling surface	sq. feet.	*477*

AIR-PUMPS.

General description and method of driving.—*Edwards patent air-pump, driven by lever from crosshead, 13 inches diameter, 16 inches stroke.*

CIRCULATING PUMPS.

General description and method of driving.—*Double-acting piston pump, driven by lever from crosshead, 8 inches diameter, 16 inches stroke.*

DATA DEDUCED FROM OBSERVATIONS.

		1st trial.	*2nd trial.*
CONDENSER.			
Cooling water passing through condenser per hour . . .	lbs.	*185635·2*	*189396*
Temperature of cooling water as it enters condenser . . .	°Fahr.	*60·6°*	*62·2°*
Temperature of cooling water as it leaves condenser . . .	,,	*71·5°*	*74·4°*
Rise of temperature of cooling water .	,,	*10·9°*	*12·2°*
Exhaust steam entering condenser per hour	lbs.	*2201*	*2314·8*
Temperature of steam as it enters condenser	°Fahr.	*141·6°*	*153°*
Temperature of steam condensed as it leaves condenser . . .	,,	*70·07°*	*73·4°*
Vacuum in condenser . . .	lbs. per sq. inch.	*13·26*	*13·25*
AIR-PUMP.			
Effective volume displaced by air-pump per minute . . .	cubic feet.	*75*	*76·6*
CIRCULATING-WATER PUMP.			
Strokes per minute		*60·94*	*62·2*

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

BOILER. SHEET I. GENERAL DESCRIPTION AND DIMENSIONS.

Type of Boiler.—*Fairbairn-Beeley*, made by *Thomas Beeley, Hyde, Manchester.* Maker's rating of the output of the boiler, *4000* lbs. of steam per hour.

Whilst the engine was being tested, the output of the boiler was *2985* and *3157* lbs. of steam per hour.

Object of Trial.—*No special test was made of the boiler, and such observations as were taken were not for that special object.*

General description of boiler and leading dimensions.—*Fairbairn-Beeley type consisting of upper shell 4 feet 6 inches diameter by 21 feet long, with steam dome 2 feet diameter by 8 feet long, and lower shell 5 feet 1 inch diameter, 18 feet long connected by steel blocks. The lower cylinder contains fire-box, 3 feet 9 inches diameter by 11 feet from front of boiler, at end of which are 107 steel tubes, 2½ inches diameter, and 1 tube 7 inches diameter, all 5 feet 6 inches long. Fire-box tubes and flue can be drawn out from front of shell.*

Method of Stoking.—*Vicars' Mechanical Stoker driven by small hydraulic motor.*

Production of Draught.—*By chimney and by jet of steam under fire bars, ⅜ inch diameter, taken from same boiler.*

Chimney height.—*123* feet *6* inches. Area at bottom *42·25* sq. feet; top *17·25* sq. feet.

Total Grate Surface (excluding dead plate) . . .		sq. feet.	*20*
Total Heating Surface (fire-box *147* sq. feet, tubes *448·14* sq. feet, ½ *upper shell 155 sq. feet, lower 283·5*) . .		,,	*1033·64*
Capacity of water space	at *5½* inches in gauge glass	c. feet.	*358·08*
,, ,, steam ,,		,,	*188·00*
Area of water surface in boiler		sq. feet.	*94·5*

Boiler set with gases from furnace dividing at back end into side flues and uniting in bottom flue at front end with one damper at back flue.

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

BOILER. SHEET II. DATA DEDUCED FROM OBSERVATIONS.

PARTICULARS OF OBSERVATIONS.

Duration of trial		*1st trial,* *10 hrs.*	*2nd trial* *6 hrs.*

FUEL.

Short description		*Durham Rough, Small.*	
Fired per hour	lbs.	*313·6*	*354·6*
Analysis by weight of dried fuel—			
Carbon	per cent.	*61·30*	
Moisture	,,	*2·04*	
Volatile matter	,,	*32·36*	
Ash	,,	*4·30*	
Calorific value (*higher*)	B.T.U. per lb.	*14564*	

ASH AND CLINKER.

Total per hour (*clinker only*)		*12·6*	*19·5*

FLUE GASES.

Not taken.

AIR AND DRAUGHT.

Not taken.

FEED WATER.

From pump	lbs. per hour.	*2985*	*3157*
Temperature of feed to boiler	°Fahr.	*270·45°*	*244°*

STEAM.

Gauge pressure	lbs. per sq. inch.	*141·0*	*140·5*
Absolute pressure	,, ,, ,,	*155·7*	*155·2*

SUPERHEATER FUEL.

Short description		*Gas Coke.*	
Fired per hour	lbs.	*89·6*	
Ash and clinker, per hour	,,	*7*	

TOTAL FUEL (coal and coke).

Fired per hour		*403·2*	*354·6*

Trial of a Steam plant at *Millbank*. Made on *3rd and 4th April, 1901.*

BOILER. SHEET III. DEDUCTIONS.

THERMAL EFFICIENCY, ETC.

		1st trial.	*2nd trial.*
Thermal efficiency of boiler	per cent.	*74·7*	*70*
B.T.U. transmitted per sq. foot of heating surface (boiler) per hour	B.T.U.	*2748*	*2979*
B.T.U. transmitted per sq. foot of heating surface (economiser) per hour	„	*244*	*214*
Fuel fired per sq. foot grate per hour . .	lbs.	*15·68*	*17·73*
Water evaporated per lb. of fuel as fired . .	„	*9·51*	*8·9*
Equivalent evaporation from and at 212° Fahr. .	„	*11·03*	*10·32*
Weight of feed per sq. foot boiler heating surface per hour	„	*2·89*	*3·49*
Gross fuel per I.H.P. per hour (including superheater)	„	*2·09*	*1·82*
„ „ „ P.H.P. „ „ „ „	„	*2·44*	*2·11*

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

ACCESSORIES. Sheet I. GENERAL DESCRIPTION AND DIMENSIONS.

Economiser.

General description of economiser and arrangement of flues, etc.—*2 Green's Economisers: each, 96 pipes, 4 feet $\frac{9}{16}$ inch diameter, 9 feet long, fitted between boiler and chimney.*

Heating surface . . . . sq. feet. *2062*

Feed Heater.

General description of feed heater and of connections to exhaust pipe, feed pump, and boiler connections.—*Fitted on exhaust pipe from low-pressure cylinder to condenser; exhaust steam on outside of tubes; feed water passed through inside tubes; 77 tubes, ¾ inch external diameter, 3 feet 6 inches long.*

Heating surface . . . . sq. feet. *52*

Superheater.

General description of superheater and of method of heating it.—*Schwoerer superheater with separate furnace consisting of 12 elements, each 8 feet 2½ inches long and 7 inches internal diameter. Grate area is 8 sq. feet. Superheater is sufficient for 480 indicated horse-power.*

Heating surface (approximately) *including ribs* . . . . sq. feet. *775*

Steam-Pipes.

General description of steam-pipe arrangements and kind of covering.—*Steel, 7 inches internal diameter covered with 2½-inch asbestos composition and black varnished. Flanges are lagged and covered with sheet steel.*

Diameter of main steam-pipe . . . . inches. *7*

Length „ „ „ „ . . . . feet. *110*

Trial of a Steam Plant at *Millbank*. Made on *3rd and 4th April, 1901.*

ACCESSORIES. Sheet II. DATA DEDUCED FROM OBSERVATIONS.

Economiser.		*1st trial.*	*2nd trial.*
Temperature of feed into	°Fahr.	*101·9*	*104*
„ „ „ out of	„	*270·45*	*244*
Rise of temperature in economiser	„	*168·55*	*140*
Feed Heater.			
Temperature of feed into	„	*72*	*83*
„ „ „ out of	„	*101·9*	*104*
Rise of temperature of feed water	„	*29·9*	*21*
Superheater.			
Steam pressure absolute into	lbs. per sq. inch.	*155·7*	
Temperature of steam into	°Fahr.	*350*	
„ „ „ out of	„	*452·5*	
Feed Pump (*on engine*).			
Temperature of feed passing through	„	*72*	*83*
Total rise of temperature of feed water (*from hot well to boiler*)	„	*198·45*	*161*
Steam-Pipes.			
Steam pressure (absolute) in boiler	lbs. per sq. inch.	*155·7*	*155·2*
„ „ engine stop valve	„ „ „ „	*151·7*	*151*
Temperature of steam at superheater end of pipe	°Fahr.	*452·5*	
Temperature at engine stop valve	„	*362·75*	
Loss of superheat in steam-pipes	„	*89·75*	
Amount of superheat at engine	„	*3·45*	

MEMOIRS.

Wilfred Daniel Bailey was born at Silvertown on 15th February 1867. He served an apprenticeship from 1882 to 1887 as a mechanical engineer in the India-Rubber, Gutta-Percha and Telegraph Works at Silvertown, where his father had been resident manager for many years, and went through the drawing office, patternmakers' and moulding shops, turning, fitting, and erecting shops. On its completion he was employed for five months as draughtsman in the same works. In May 1888 he went to Buenos Aires as assistant in the branch works of the firm, and was also engaged in general engineering work, and in the installation of all kinds of machinery. In 1897 he entered into partnership with Mr. L. Walker as electrical and general engineers, the title of the firm being Bailey, Walker and Co. They soon acquired a leading position in business, and there was every prospect of a successful future, when his partner's death occurred. This was followed shortly afterwards by his own death taking place from typhoid fever, after three weeks' illness, at Belgrano, Buenos Aires, on the 1st December 1901, in his thirty-fifth year. He became a Graduate of this Institution in 1888, and was transferred to full membership in 1900.

Samuel Dixon was born at Marple, near Stockport, on 3rd September 1849. Having been educated at Elnor Lane School, Whaley Bridge, he was apprenticed to the late Mr. Samuel Brooks, of Gorton, Manchester. He remained there only a short time, and then went to Messrs. Kendall and Gent's machine-tool works at Salford. During his apprenticeship he devoted his leisure hours to study, and attended the evening classes at the Manchester Mechanics' Institute and at Owens College. As the outcome of these studies, he succeeded in securing a Whitworth Scholarship, being the first of his year. This success entitled him to a course of three years' study at Owens College, during which he matriculated, and passed the first examination for the degree of Bachelor of Science. He then returned to Messrs. Kendall and Gent as works manager, and in 1880 became a partner. From that time he travelled a good deal on the Continent in the interests of his firm. He attended the Paris Exhibition of 1900, where Messrs. Kendall and Gent were exhibitors, and it was there that the first symptoms of his illness appeared, which has been the indirect cause of his death. He was President of the Manchester Association of Engineers for 1888 and 1889, and was also President for 1899, in succession to Colonel Dyer, of the Engineering Employers' Federation. He contributed in 1894 a Paper* to this Institution on "Drilling Machines for Cylindrical Boiler Shells." He was keenly interested in technical education, and succeeded in establishing a continuation school at Marple; he was also a member of the Marple Urban Council from 1893. In the autumn of 1900 his health compelled him to abstain from all active work, and in 1901 he retired from the firm, and finally consulted two specialists, who recommended a critical operation. This was successfully performed in London, but pneumonia supervened, and he gradually sank and died. His death took place in London on 17th January 1902, at the age of fifty-two. He became a Member of this Institution in 1883.

ROBERT HOLDEN was born in Blackburn on 5th January 1844. In 1868 he commenced an apprenticeship in the engineering works of Messrs. Harper and Sames, at Church, near Accrington, and on its termination in 1872 went as improver at Messrs. W. and J. Yates, now Messrs. Yates and Thom, of Blackburn. From 1874 to 1877 he worked as a journeyman fitter, and then was promoted to be foreman. Subsequently he became outdoor manager and superintendent. During this latter position he had the entire charge of nearly all their contracts in the various parts of the country. In 1895 he obtained in open competition the appointment of superintendent mechanical engineer to the County Borough of

---

* Proceedings 1894, page 506.

West Ham. This position he held until the time of his death, which took place at his residence in Canning Town, on 31st January 1902, at the age of fifty-eight. He became a Member of this Institution in 1899.

CHARLES LAFAYETTE HUNTER was born at Tredegar, Monmouthshire, on 29th October 1839, and was the son of the late Mr. Charles Hunter, estate agent to the old Tredegar Iron and Coal Co., and who was for many years High Constable of Tredegar. He was educated at Long Ashton School, near Bristol, and in 1853 was apprenticed to the Tredegar Iron Co. as a mechanical engineer. He made such rapid progress in his profession that in 1860 they appointed him their chief engineer, and locomotive superintendent of their Sirhowy Railway (a line which was subsequently taken over by the London and North Western Railway Co., and which is still known as the Sirhowy Branch). In 1869 he was further promoted to the position of works manager, retaining the engineering responsibilites as heretofore, and continued in those positions until the Works were purchased by a new company in 1874, when he resigned. He was also on several of the local public authorities during his residence in Tredegar.

In 1875 he removed to Cardiff where he started in practice as a consulting engineer, and continued in this till 1882, when he became Chief Mechanical Engineer to the Trustees of the late Marquis of Bute, Bute Docks, Cardiff (the title so far as the Docks are concerned being at a later period changed to that of the Cardiff Railway Co.); and in 1889 he succeeded the late Mr. John McConnochie as Chief Engineer, which position he retained till his decease. During his twenty years' connection with the Bute Docks he carried out many important engineering works, among which may be mentioned the equipment of the Roath Dock, the modernising of the coaling tips etc. at the East Dock, the construction of several large grain, meat chilling, and cold storage warehouses and numerous other works, and was responsible for the design of the system of shipping coal known as the Lewis and Hunter System in use at the Roath Dock, Cardiff, which has proved so great a success and such an acquisition to the port. At the time of his death he was joint engineer with Mr. George N. Abernethy for the construction of the New South Dock, which is nearing completion at Cardiff. His death took place at his residence in Penarth, near Cardiff, on 8th February 1902, in his sixty-third year. He became a Member of this Institution in 1889.

LUKE LONGBOTTOM was born in Wakefield on 2nd March 1826. He served part of his apprenticeship with Messrs. Fenton, Murray, and Jackson, of Leeds, and completed it with Mr. E. B. Wilson, Railway Foundry, Leeds. He then joined the firm of Messrs. Kitson, Thompson, and Hewitson, of Leeds, as leading hand at locomotive building, and afterwards went as works manager to Messrs. Bray and Waddington, of the same city. In 1855 he went to be general engineer to the Kendal and Windermere Railway Co. On its amalgamation with the London and North Western Railway in 1860, he was taken over by the latter company, and remained in their service until December 1882, when he was appointed locomotive, carriage and wagon superintendent of the North Staffordshire Railway. This position he held until the time of his death, which took place suddenly at his residence in Stoke-on-Trent, on 12th February 1902, in his seventy-sixth year. He became a Member of this Institution in 1884; and was also Vice-President of the Association of Railway Engineers.

JOHN MCTAGGART was born in Paisley on 2nd June 1865. He received his education at a private school, and afterwards at the Paisley School of Art. From 1880 to 1885 he served his time in the engineering works of Messrs. Fullerton, Hodgart, and Barclay, of Paisley. In 1886 he was engaged as outside foreman in the works of Messrs. A. F. Craig and Co., Paisley. In 1887 he entered as junior engineer the service of the British and African Steam Navigation Co., of Liverpool, and remained in their service for six years, the last two of which were served as chief engineer on one of the mail steamers. In 1893 he was appointed manager and engineer of the several Destructor Works belonging to the Bradford

Corporation, and he had also engineering supervision over the machinery at the different Hospitals throughout that city. Among the various improved methods of working the destructors, which he initiated, was that of the disposal of the clinker from the furnaces, and he so managed that the whole of the residuum or clinker was utilized in some form or other at the different depôts. In conjunction with the City Surveyor, he devised an overhead railway for the removal of clinker from the furnaces, and also a complete clinker crushing and screening machine, both of which have met with considerable success.

In 1898 the duties of superintending the removal of house and other refuse throughout Bradford were entrusted to him, the work having previously been carried out by contract. He devised and installed a plant for making concrete slabs and bricks from destructor refuse, which worked successfully; and he also laid down a special plant for converting fish refuse into manure. At all the destructors under his supervision electric-lighting installations were erected, and the power required for this purpose, as well as for all the machinery at the depôts, was obtained from the burning refuse. He was instrumental in founding the Cleansing Superintendents' Association of Great Britain, and in 1900 was elected its President. At the Meeting of the British Association in Bradford in 1900, he contributed a Paper on the "Disposal of House Refuse in Bradford." His death took place in Bradford from acute pneumonia on 5th January 1902, in his thirty-seventh year. He became an Associate Member of this Institution in 1899.

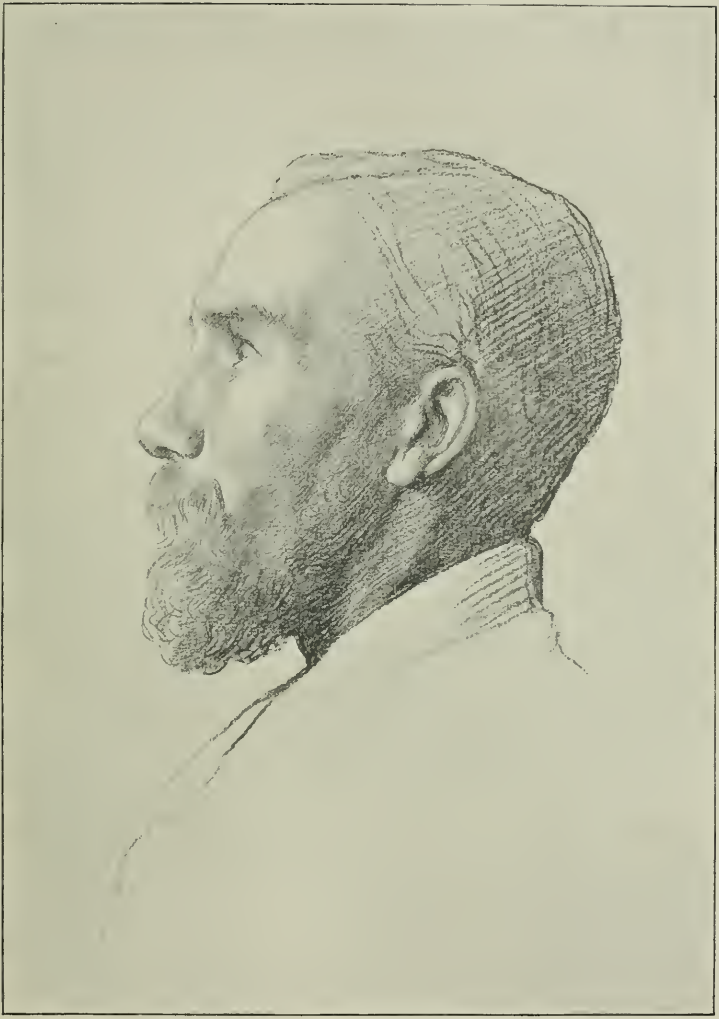
John Adam Munn was born in Glasgow on 4th May 1870. He was educated at the public school at Newton Mearns, near Glasgow; and afterwards at Allan Glen's Technical Institution, Glasgow. From 1886 to 1890 he attended evening classes at the Glasgow and West of Scotland Technical College, and passed several of the Science and Art Department examinations at South Kensington. From 1886 to 1888 he served his time with Messrs. Watson, Laidlaw and Co., Glasgow, at pattern making; from 1888 to 1889 with Mr. John Bennie, hydraulic and general engineer, at turning and fitting;

and from 1889 to 1891 with Messrs. G. and J. Weir, Cathcart, near Glasgow, at turning and fitting. After working a short time as journeyman erector with Messrs. R. Napier and Sons, shipbuilders, Glasgow, he entered the drawing office of Messrs. J. M. Adam and Co., of Govan, where he remained until 1894, the latter part of the time being employed as outside foreman. He was next employed for a few months as fourth engineer on the s.s. "Borderer," and then returned to Messrs. R. Napier and Sons as journeyman erector for a short time, after which he was engaged in erecting and overhauling machinery in his father's works at Dalmarnock, Glasgow. In March 1895 he went as engineer on board steamers of the British India Steam Navigation Co., Calcutta, and obtained a second engineer's Board of Trade Certificate. In 1896 he was appointed works manager with Messrs. W. R. Philp and Co., of Calcutta, and in the next year became engineering traveller to the Planters' Store and Agency Co., of Calcutta, remaining in this capacity one year, when he entered Messrs. K. L. Mukerjee and Co.'s Works as general manager. In the beginning of 1900 he was offered and accepted an appointment in the North Cachar Hills, as a contractor's agent under Messrs. Lewis Jones and Co. (Bott and Stennett), in the construction of a branch of the Assam Bengal Railway, where amongst other works there was a considerable amount of difficult tunnelling. In May 1901 he caught a severe chill from which he never recovered, and died on his way to Calcutta at Giridih, on 30th November 1901, in his thirty-second year. He became an Associate Member of this Institution in 1899.

Almond Rowe was born at St. Just in Penwith on 14th January 1848. He served his time from 1862 to 1868 in the engineering works of the Botallack Mining Co., St. Just, Cornwall; and at its completion was engaged at the same works as assistant superintendent and draughtsman until 1872. In 1876 he proceeded to Singapore to superintend the construction and erection of rice mills for Messrs. Howarth, Lyon, and Erskine. In 1880 he was appointed government engineer surveyor at Penang, Straits Settlements, and in 1888 was transferred to Singapore where he became senior government marine surveyor and examiner of engineers for the Straits Settlements. This position he held until his retirement in March 1901, when he returned to Penzance, where his death took place on 25th May 1901, at the age of fifty-three. He became a Member of this Institution in 1892.

John Taylor was born at Lower Broughton, Salford, on 8th February 1866. Having served his time from 1879 to 1886 in his father's works (Messrs. Thomas and Taylor, laundry engineers, of London and Stockport), he was then engaged by them as traveller; and in 1890 was appointed manager of their London works. He designed and superintended the erection of public laundries, baths and wash-houses, and dairies, all over the United Kingdom, in several of which he installed electric lighting. His death took place on 3rd January 1902, in his thirty-sixth year. He became an Associate of this Institution in 1890.

George Scholey Young was born in Stepney on 17th February 1850. Having been educated at Poplar Academy and at the City of London College, he served an apprenticeship at his father's works at Blackwall from 1866 to 1871. On its completion he was employed as draughtsman, and afterwards as manager until 1881, when he became a partner, and continued the management of the business until 1891. During that period he designed and superintended the manufacture of about 120 sets of paddle-wheel, single screw and twin screw machinery of all types up to 900 indicated horse-power, and various mill and other machinery. In January 1891 he was appointed marine and mechanical engineer to the Thames Ironworks and Shipbuilding Co., and has been responsible for the design and manufacture of the whole of that branch of the company's work up to his death. He also carried out the construction and fixing of the machinery for the new precipitation works at Crossness under Sir Alexander Binnie. Latterly he was engaged as engineer and manager of the same company's works at Greenwich, which had formerly belonged to Messrs. John Penn and Sons, and there carried out work for the Admiralty, comprising among others three sets of machinery of 18,000 horse-power each. He was joint inventor of a water-tube boiler, of which a considerable number have been constructed. Since he had been at Greenwich, he remodelled the engine shops, and designed, erected, and equipped their new shops for the manufacture of water-tube boilers. His death took place at his residence in Lee, Kent, after a painful illness, on 11th February 1902, at the age of fifty-two years. He became a Member of this Institution in 1879.



From a Pencil Drawing, 1884. *By permission of the Artist, A. Legros.*

Yours faithfully
Alexr B. W. Kennedy

PRESIDENT, 1894–95.

The Institution of Mechanical Engineers.

PROCEEDINGS.

10th March 1902.

A Special General Meeting was held at the Institution on Monday, 10th March 1902, at Half-past Five o'clock p.m.; William H. Maw, Esq., President, in the chair.

The requisite quorum of thirty Members being present, the following Special Resolution of the Institution, which had been passed at the Annual General Meeting on 21st February 1902, was put to the Meeting, and was confirmed:—

"That the following Article be substituted for the existing Article 23 of the Articles of Association of the Institution—

> "Article 23.—The Council of the Institution shall be chosen from the Members only, and shall consist of one President, six Vice-Presidents, twenty-one ordinary Members of Council, and of the Past-Presidents. The President, two Vice-Presidents, and seven Members of Council (other than Past-Presidents), shall retire at each Annual General Meeting, but shall be eligible for re-election. The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree otherwise among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot."

The Meeting then terminated. The attendance was 46 Members and Associate Members.

The Institution of Mechanical Engineers.

PROCEEDINGS.

21st March 1902.

An Ordinary General Meeting was held at the Institution on Friday, 21st March 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The President said he had the painful duty of referring to the death of one of their Vice-Presidents, Mr. Bryan Donkin, which had taken place since the last Meeting. Mr. Bryan Donkin had been a very valuable Member of the Institution. He had been a Member since the year 1873, and for the last seven years had been on the Council, and for two years held the office of Vice-President. He had contributed several very important Papers to the Proceedings of the Institution, had served on three Research Committees, and had promoted the interests of the Institution in every way within his power. At the Council Meeting that afternoon it had been unanimously determined that a letter of condolence should be sent to Mrs. Bryan Donkin, expressing the Council's sincere sympathy with her in the great loss she had sustained; and the President felt sure that the Members would wish to associate themselves with the Council in the action the latter had taken. Many of the Members had, like himself, lost a very sincere personal friend in Mr. Donkin, and all regretted a death which had deprived the Institution of so valued a Vice-President.

The Minutes of the previous Meetings were read and confirmed.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following fifty-one candidates were found to be duly elected :—

MEMBERS.

Baird, David George,	Dublin.
Boak, William,	Madras.
Bryson, James,	Mid-Calder, N.B.
Franklin, Edward Stanley,	London.
Gibbs, George James,	York.
Hulley, Richard Dodson,	Manchester.
Jeffreys, John,	London.
Jepson, James Thomas,	Leeds.
Savage, John Thomas,	King's Lynn.
Slater, James George,	Newark.

ASSOCIATE MEMBERS.

Åkerlind, Gustaf Fredric,	Aughnacloy, Ireland.
Allen, Harold Gwynne,	Bedford.
Armistead, Thomas Webster,	Liverpool.
Berry, Frederick,	Bolton.
Codd, Thomas James,	London.
Hall, John Edward,	London.
Haste, Frederick Charles,	London.
Hinchliffe, George William,	Leeds.
Hyde, George,	St. Helens.
Kenshole, Henry Harding,	Ilford.
Loscher, Albert Paul,	Manchester.
Mayo, Charles Robert,	London.
Murphy, William,	Manchester.
Nixon, Charles Basil,	Manchester.
Orr, Thomas Reginald James,	Birmingham.
Pritchard, William Elias,	Port Dinorwic.
Ritchie, Andrew Mackie,	Johannesburg.
Smith, Walter Tom,	London.
Stow, George,	Ashford, Kent.

Vernon, Horace,	Manchester.
Wayte, James Benjamin,	Dublin.
Wilkinson, Francis Alan,	London.
Woodeson, William Armstrong,	Gateshead.
Yerbury, Harry Edward,	Sheffield.

ASSOCIATE.

Grierson, Henry Forster,	London.

GRADUATES.

Adams, William John,	London.
Coueslant, Leopold Daniel,	Huddersfield.
Devin, Ernest Hurley,	London.
Funnell, Herbert Nicholas,	London.
Gregory, Herbert George,	London.
Hewett, John Ridge,	London.
Montague, Graham,	Gloucester.
Nicholson, Edward,	Leeds.
Parratt, Herbert Edwin,	Derby.
Penn, Bertram Harley,	London.
Radley, Willie John Peace,	Halifax.
Reeve, Edward,	Birmingham.
Shimmin, George Featherstone,	Maryport.
Smith, Ernest Edward,	London.
Spear, Charles Oscar,	London.
Whittington-Cooper, Alfred,	London.

The President informed the Members that the Council had appointed Mr. A. Tannett-Walker to fill the vacancy of Vice-President, caused by the death of Mr. Bryan Donkin. The new rule passed at the last Meeting provided for the addition to the Council of six new Members; the vacancies thus created and the additional vacancy in the Council caused by Mr. Tannett-Walker becoming a Vice-President had been filled by the Council selecting the following gentlemen, who would retire at the next Annual General Meeting, and would then be eligible for re-election :—

Members of Council.

Edward B. Ellington,	London.
Henry Lea,	Birmingham.
James Mansergh, F.R.S.,	London.
John F. Robinson,	Glasgow.
John W. Spencer,	Newcastle-on-Tyne.
John Tweedy,	Newcastle-on-Tyne.
Henry H. West,	Liverpool.

The following Papers were read and discussed collectively :—

"Fencing of Steam- and Gas-Engines"; by Mr. Henry D. Marshall, *Member of Council.*

"Fencing or Guarding Machinery used in Textile Factories"; by Mr. Samuel R. Platt, *Member of Council.*

"Protection of Lift-Shafts, and Safety Devices in connection with Lift-Doors and Controlling Gear"; by Mr. Henry C. Walker, *Member*, of London.

"Guarding Machine Tools"; by Mr. W. H. Johnson, of Manchester.

The President announced that, as the Discussion had not been concluded, an Extra Meeting would be held on Friday, 4th April.

The Meeting terminated at Ten o'clock. The attendance was 104 Members and 72 Visitors.

PROCEEDINGS.

4th April 1902.

An Extra Meeting was held at the Institution on Friday, 4th April 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The Discussion on the Four Papers on the "Fencing of Machinery" was resumed and concluded.

The Meeting terminated shortly before Ten o'clock. The attendance was 73 Members and 39 Visitors.

FENCING OF STEAM- AND GAS-ENGINES.

By Mr. HENRY D. MARSHALL, Member of Council.

The author having been requested to submit a short Paper upon the Protection of Steam- and Gas-Engines, with a view to diminishing the risk of accidents to the attendants, fears, however, it is a subject limited in its scope. The various types of steam-engines have been redesigned by the leading makers during the last decade, and embody in a large measure provision for protecting the moving parts. The author will briefly review the usual modern practice in this regard, and make a few suggestions for additional safeguards not generally included in the standard equipment.

In arranging guards on steam and other similar engines the contingency to be kept in view is to provide ample protection for the attendant, without rendering the moving parts, bearings, &c., difficult of access, as this may contribute to neglect on the part of the attendants, and result in damage to the engine.

In a well-appointed works or factory, the engine-room should be separate from the shops and other departments, and be so arranged that none of the operatives or members of the staff have occasion to pass through or into it, and in cases where this is not practicable,

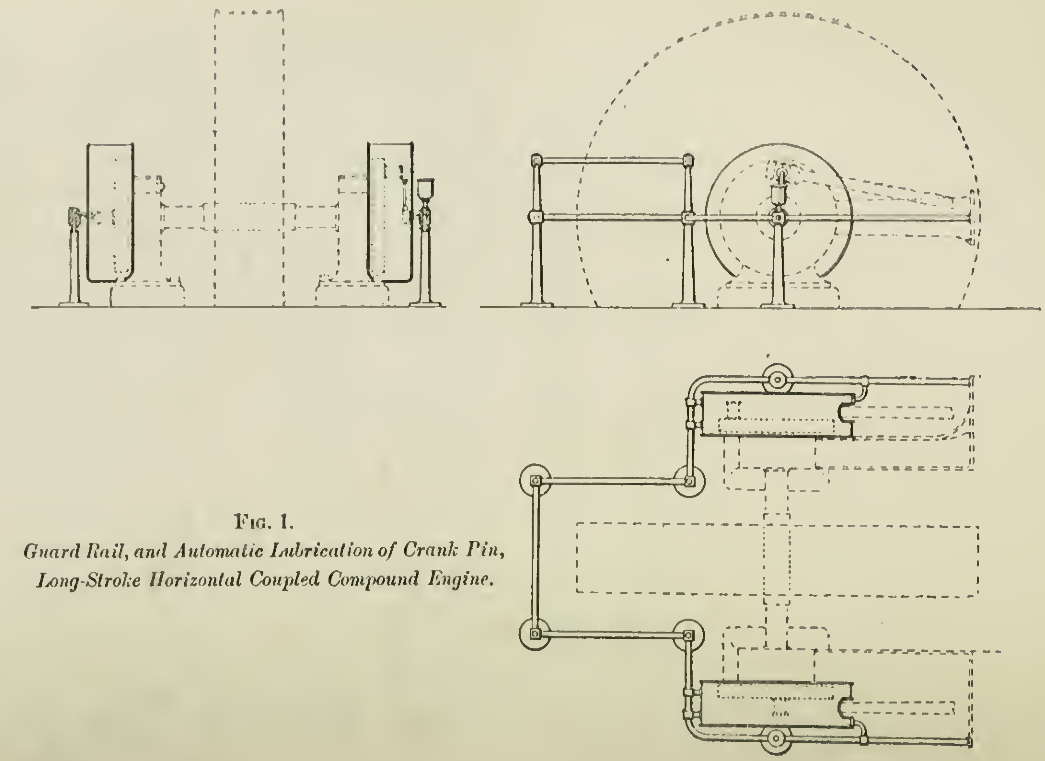


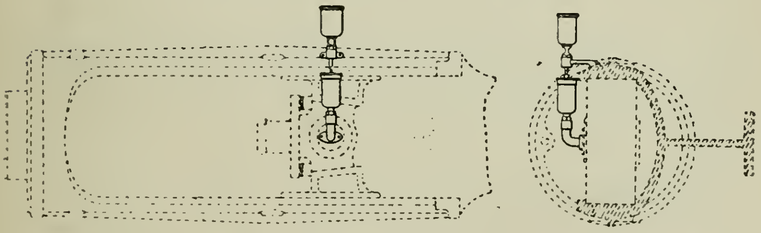
Fig. 1.

Guard Rail, and Automatic Lubrication of Crank Pin, Long-Stroke Horizontal Coupled Compound Engine.

the engine should be enclosed by a rail or screen within which none but the attendant or other authorised person is allowed. In addition to this, however, certain guards and rails should be provided on the engine; and the author will take as a typical case a long-stroke horizontal coupled compound engine, and describe briefly what is the usual equipment. These engines are now made chiefly with the girder type of bed, the crosshead being thus safeguarded within the slides, and an additional protection is frequently provided by running a rail along the open side of the guide path up to the cylinder. In some cases the crosshead path is entirely closed by removable casings made of light material, with handles and fixings which permit of ready manipulation. From the other end of the guide path the rail should extend beyond the crank or disc, and return either to the main bearing or a pillar placed in a convenient position. There should also be a pillar opposite the centre of the crankshaft which can be utilized for supporting the rail at this point, and also for carrying a lubricator to supply the crank-pin with oil, the latter being fed from the lubricator into a small receiver carried from the crank-pin by a tube, as shown in Fig. 1, thus making the lubrication at this point automatic, and obviating the necessity of the attendant touching any moving part when replenishing the supply of oil. The lubrication of the crosshead pin can also be effected from a stationary lubricator by leading a pipe therefrom to a point over the oil-box on the crosshead, and fitting this oil-box lid with what is known as a "licker," so that at each stroke of the engine a drop of oil is wiped off the end of the

Fig. 2.

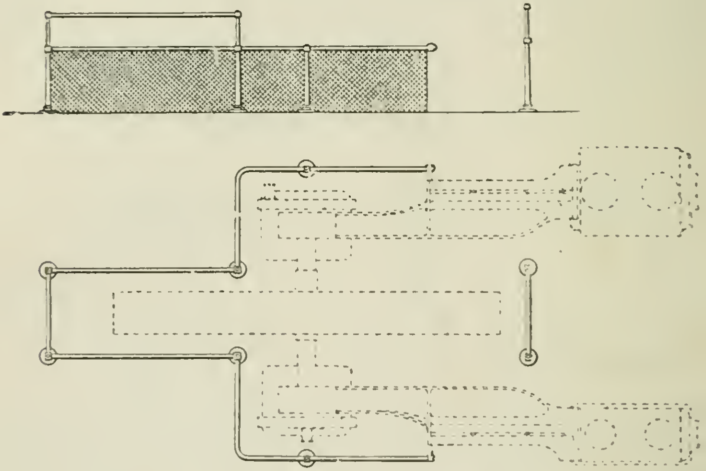
Lubrication of Crosshead Pin by "licker."



tube leading from the stationary lubricator, and finds its way into the oil-box on the crosshead and thence to the crosshead pin, Fig. 2 (page 213). A desirable refinement in an engine is a system of continuous lubrication; this is adopted in several large factories and installations of machinery. By means of a force pump which circulates oil through the principal parts of the engine, a continuous feed is maintained, the oil being collected, filtered and used over again.

FIG. 3.

Double Rail-Guard fitted with rigid Wire Netting.



In enclosed type self-lubricating engines it is an essential feature to have a continuous flow of oil, which may be effected either by splash, or forced through by a pressure of about 10 to 15 lbs. per square inch. Any such systems protect the attendant in some cases as much as a great amount of fencing, although this may be demanded by the requirements of the Factory Act. Where the arrangement of the drive will permit of it, the rail (preferably double) should be continued round the fly-wheel, and in any case the belt or rope race should be suitably fenced. The fly-wheel may also be entirely boarded in on both sides, thus preventing anything falling into the arms of the wheel. Where the race is sunk below the floor level, and the sides are accessible, a light screen, such as rigid wire netting or fender board, may be fixed from the bottom rail to the floor to prevent anything rolling from the floor into the belt race, as illustrated on Fig. 3 (page 214).

Where the cylinders have extended rods working through the back cover, the slipper path should be guarded by a cover; or where an air or other pump is driven from this point by rocking levers, guard rails should be provided round the moving parts above the floor level, a fender plate or screen being provided round the opening in the floor, similar to that described for the belt race. A splasher plate, encircling the crank or disc with a slot for the connecting-rod to work through, as shown on Fig. 1 (page 212), makes an efficient guard for these revolving parts, and also prevents the oil being thrown about.

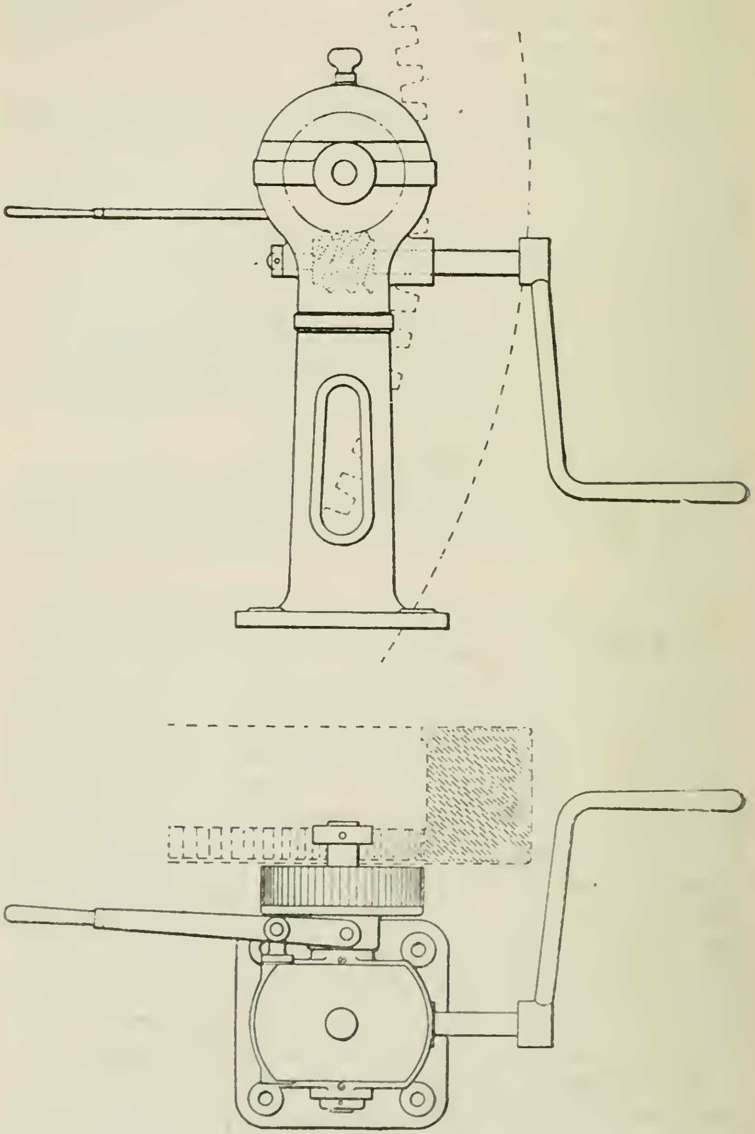
In cases where the governor is chain-driven, and the bracket carrying the chain-wheel projects, the railing should be arranged to guard this, or other suitable protection be provided, such as a light case over the chain and wheels to prevent the attendant's clothing catching.

It is now usual, except with quite small engines, to provide a means of racking the engine round by hand before steam is admitted to the cylinder, and the mechanism used for this purpose should be so arranged that, when the engine commences to be driven by the steam, the turning gear is automatically thrown out of action, thus preventing the risk of accident to the attendant when using the turning gear. A convenient and powerful type of turning gear is shown on Fig. 4 (page 216), from which it will be seen that a toothed pinion engages with a rack on the fly-wheel rim, this pinion being operated by a handle through the medium of a worm and worm wheel. The pinion in question is loose on the spindle or shaft, and has a ratchet engagement so that it runs free when the engine starts, until thrown out of gear by the lever as shown, thus preventing any danger of the operator being caught by the turning handle.

In addition to guarding the moving parts of an engine, care should be taken in arranging the drains from the cylinders or other

FIG. 4.

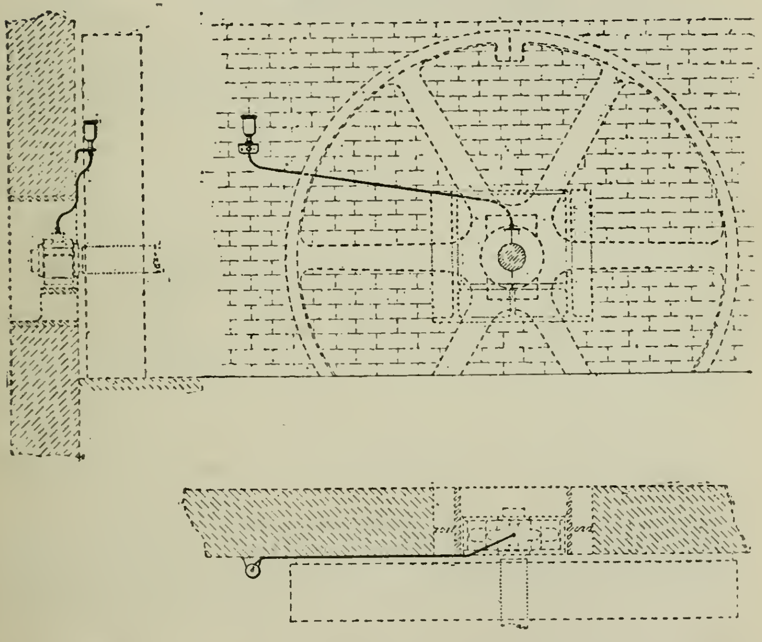
Safety Turning Gear.



parts subject to steam pressure, so as to avoid any risk of the attendant being scalded by the steam blowing back through the overflow from a steam-trap, which may be the case with some types of trap, if the pipes subject to pressure are coupled to the trap overflow, which should therefore be avoided if possible. Efficient arrangements should also be made, and suitable relief valves provided to prevent any accumulation of water in the engine cylinder, as many serious breakdowns have occurred from this cause. These latter points are perhaps outside the exact subject now under consideration, although they have to be considered in the safe running of an engine.

FIG. 5.

Safety Lubricator for Wall-Box Bearing.

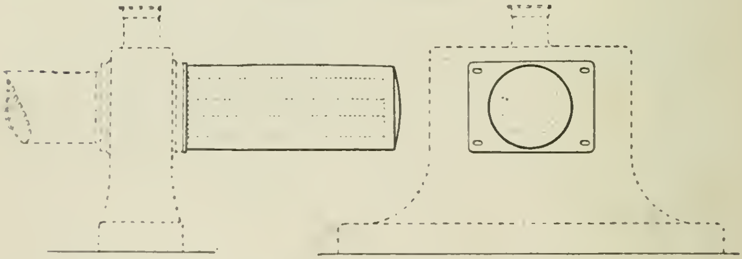


In addition to the type of engine just mentioned there are also in general use the following nine classes of engines:—

(*a*) The Tandem Compound Engine.
(*b*) Single-Cylinder Long-stroke Horizontal.
(*c*) Short-stroke Horizontal self-contained engine with shaft extending beyond bearings.
(*d*) Vertical Engines and Enclosed Types.
(*e*) Portable and Semi-portable Engines of the overhead type.
(*f*) Undertype Engines.
(*g*) Winding and Hauling Engines.
(*h*) Traction Engines and Road Rollers.
(*i*) Gas and Oil Engines.

The author's remarks with reference to the coupled compound engine apply equally to (*a*) and (*b*), the features now under consideration being practically the same; but in cases where the outer bearing of the crankshaft is carried in a wall box, and the fly-wheel or pulley is placed in close proximity to the wall, means should be provided for lubricating the outer bearing without the attendant having to pass his oil-can through the arms of the wheel, or between the same and the wall. A convenient arrangement to meet this may be effected by carrying the lubricator on a bracket fixed to the wall, or in any accessible position, and leading a pipe from same to the bearing as shown in Fig. 5 (page 217). Or by a self-lubricating pedestal of the Mohler type, which only requires replenishing at intervals, which can be done during the time the engine is standing. With (*c*) the guarding required is somewhat less elaborate, as most

Fig. 6.
Guard for Shaft End.



of the moving parts are within the engine frame, but when the shaft end projects beyond the bearing or driving pulley a sleeve of sheet brass or other suitable material will be found useful to prevent the rotating end of the shaft (in which there is usually a keyway) catching the attendant's hand or clothing. When there is no pulley outside the bearing, the sleeve can be pinned to the side of the bearing by suitable small screws, as shown in Fig. 6 (page 218), and in the case where a pulley is required, the sleeve can be carried by a pillar.

This arrangement is also applicable to vertical engines (*d*), and with this type there is little else required, except a suitable fence for the fly-wheel and belt, or ropes. For the enclosed or boxed-in types of engines usually running at a high speed, special provision is made in the design for closing in all the moving parts, the only part requiring extra protection being the transmission, and as these are generally direct coupled to a dynamo, or other quick rotating machine, the usual mode of fencing is to case in the fly-wheel.

With portable and semi-portable engines (*e*), it is not usually considered necessary to provide anything which may be strictly designated a guard, but the arrangement previously mentioned for shielding the projecting end of the shaft is sometimes adopted, and where the piston-rods pass through the cylinder back covers, there should be a sleeve extended from the gland inside which the rod works.

In the case of under type engines (*f*), practically the whole of the moving parts, except the shaft ends and fly-wheel or pulley, are within the frame and under the boiler, so that, when an efficient arrangement is provided for lubricating the different points, there is no necessity for guards except round the wheel and belt race. With this type of plant the water-gauge glasses on the boiler front should have suitable protectors to prevent the attendant being injured, should the glasses burst while under steam pressure.

Winding and hauling engines (*g*) may be treated on the same lines, so far as the engine work proper is concerned, as the self-contained horizontal type. The gearing, etc., outside the engine should be fenced or guarded as the circumstances of each particular case may require.

Traction engines and road rollers (*h*) should have a light cover over the gearing which transmits the motion from the engine crank-shaft to the road wheels. Protectors should also be provided on the water-gauge glasses, and further than this there is not much scope or necessity for guards on these engines.

Gas- and oil-engines (*i*) are so closely allied in general form with steam-engines, that the remarks and suggestions *re* guarding may be taken as broadly applicable in both cases.

Except in cases where the engines are not self-starting, the fencing round the fly-wheel should be such that the attendant has easy access, or else in very small engines this should be removable.

The author might also add as a recommendation, that in starting off steam- or gas-plants the engines should be moved slowly for a few revolutions, especially in steam-engines, where there is a liability for water to lodge in lengthy steam-pipes, which are often carried a considerable distance, sometimes in the open and not always properly clothed. An efficient steam separator, close to the stop valve of a steam-engine, is a desirable accessory. In conclusion, the author would specially mention that all oil-boxes and reservoirs containing lubricants should be carefully cleaned from time to time to ensure regular and efficient lubrication, and they should also be placed in a convenient and easily accessible position to ensure proper care and attention from the engineer in charge.

As a rule, except under exceptional circumstances, the moving parts of an engine should not be cleaned whilst it is in motion.

The subject is illustrated by 7 Figs. in the letterpress, and Plate 9.

(*For Discussion, see page* 248.)

FENCING OR GUARDING MACHINERY USED IN TEXTILE FACTORIES, WITH SPECIAL REFERENCE TO MACHINERY USED BY COTTON SPINNERS AND MANUFACTURERS.

By Mr. SAMUEL R. PLATT, *Member of Council.*

At the request of the Council, the following Paper has been prepared to show the provision made by the author's firm, Messrs. Platt Brothers and Co., of Oldham, for guarding the dangerous parts of machines made by them, and all or any portion of these devices may at an extra cost be applied according to circumstances. An examination of the illustrations will show that in some cases the guards or covers, and the locking apparatus connected with them, are somewhat elaborate in design and costly to construct; but it should not be overlooked that it is not merely necessary to provide guards, but to make these, as far as possible, in such a manner that they cannot be entirely removed by careless or indifferent workpeople. It is not uncommon to find machines, after working a few years only, in what may be regarded as an unsafe condition, owing to the original guards furnished by the maker having been broken, lost, or taken away for one reason or another. It is therefore advisable, in all cases where practicable, to make hinged guards which can be moved on their hinges and opened when required, but cannot be detached from the machines without some extra labour being necessary to accomplish this.

It may be taken as a fact, that workpeople or overlookers are not as a rule in favour of the application of guards, because they interfere with the accessibility of the working parts of the machine, and in many cases are a source of additional trouble to the operatives in removing or refixing. They also increase the difficulties of oiling and lubricating, as well as the number of parts to be cleaned. For these reasons many special guards do not find favour with mill-owners, particularly as extra guarding involves additional cost without increasing the efficiency of the machines as regards the production of yarn or cloth.

The more elaborate guards have been gradually introduced in recent years, to a great extent for the protection of mill-owners against careless and incompetent workpeople, or in other words, to protect workpeople from their own careless actions. The improved guards not only cover the working parts likely to injure the attendants, but are constructed in such a manner that they cannot easily be removed or taken entirely away from their respective places in the machine. Several, as will be shown later, do not even permit the machines to run, unless they have been replaced in proper position.

The special guards have in some instances been designed to suit the requirements of mill-managers on the Continent of Europe, notably those in Russia, where the factory inspectors are very arbitrary, and the factory laws and regulations so worded that the mill-manager or director is made personally liable for any accident or damage to the workpeople; and the mill-owners have not only to pay compensation to the person injured or to relatives, but in case of serious injury the manager is liable to imprisonment in addition—no light punishment. The workpeople in Russia, being drawn mostly from the peasant class, taken from their occupations in husbandry or forestry, are generally ignorant and illiterate. It can therefore be readily imagined that the responsible director of a factory will not hesitate, under such circumstances, to incur considerable expense in providing safeguards to reduce his chances of imprisonment and monetary loss. It is not uncommon to hear of workpeople who are said to have deliberately put their fingers in a working part of a machine, especially to injure the trigger finger, with the object of injuring it just so much as to render themselves unfit for military service. The factories in some districts of Russia are worked night and day with three or four sets of workpeople, therefore precautions are more generally necessary and advisable.

In our own factory districts such arbitrary measures are not imposed upon directors, or managers, but there is the Employers' Liability Act to be borne in mind, and for this and other reasons the provision of special guards, in addition to those generally considered necessary, is advisable. The factory inspectors in this country however, generally use their power and influence in making the use of special guards compulsory and not optional, and do all they can to secure the safeguarding of machinery. Notwithstanding the inconvenience of guards more or less elaborate and the slight increase in the first cost of the plant, this question of guarding is worthy of serious consideration, and it is probable that when the charges for accidents are set against the cost of special guards, the greater initial outlay will ultimately prove the cheaper, and will in the long run give more satisfaction to employers and employed. More protection ought, however, to be afforded to employers, against workpeople who neglect to avail themselves of the safeguarding provided by the mill-owners.

In the processes of cotton preparing, carding, and spinning, the first machines through which the cotton is usually passed are the Bale Breaker and the Exhaust Opener. The Bale Breaker is made in various ways, but in the pattern hitherto chiefly used, the machine is fed by means of a continuous lattice on which the attendant spreads the raw cotton which the lattice conveys to the feed rollers. A newer type of machine known as the Hopper Bale Breaker is however now rapidly displacing the older form of machine, and in this later pattern the possibility of injury to workpeople and liability to fire, are reduced to a minimum. The feeding of the Exhaust Opener is also by a lattice, either by hand or, more generally and preferably, by an automatic Hopper Feeding Machine. To prevent the attendant putting the hand carelessly or without thought into the taking-in or feed rollers of the older pattern of Bale Breaker whilst spreading the cotton, also to prevent the attendant picking any cotton which may have wrapped round the upper feed rollers whilst the machine is running, a skeleton guard as shown on the illustration, Fig. 1, Plate 10, is applied. This should be of such a length from the taking-in or feed rollers, that even if the arm be pushed under up to the elbow joint, the finger tips cannot touch the nip of the rollers. The guard is made of an open pattern so that roller laps if formed may be readily seen.

The single beater Scutcher is usually fed by four laps taken from the Opener, and the skeleton guard previously shown is not necessary, but a light self-weighted dummy roller is sometimes placed above the lattice, before the actual working roller, and this dummy roller will not cause injury to the hand if put beneath it.

At the front of the Opener and Scutcher a lap is formed, in the centre of which is an iron lap roller of considerable weight. At the commencement of a new lap this roller is dropped by hand on the layer of cotton as it comes from the machine, and the layer is then turned over and behind the lap roller, and the end usually tucked under by hand. Attendants not very expert are liable to get their fingers or hand trapped during this operation, and to prevent this, a board full width of the lap, Figs. 2 and 3, Plate 10, with arms at each end and elbow joints, is sometimes used. This is quite effective for the purpose of turning the layer of cotton over and behind the lap roller, and so does away with the necessity of using the hand for this purpose.

The vertical racks with anti-friction bowls on the top, which serve to give the requisite pressure to the lap roller, have to be raised by the large hand-wheel on the right side of the machine; and to enable the racks to be wound up, the friction is taken off the brake wheel by means of a treadle. To prevent the attendant allowing these racks to come down into position over the ends of the lap roller with a run, a supplementary lever, operated by a stud on one of the racks when it nears the bottom, lifts the attendant's foot off the brake treadle and allows the friction or brake to come into action, thus stopping the downward run of the pressure racks and preventing breakages, as well as injury to the workpeople's hands. The illustration in Fig. 4, Plate 10, shows the treadle connected the full width of the machine, and not on one side only as usual. This treadle, when pressed downwards, lifts the pressure off the rack.

The two or three-blade beater in machines of this type is run at speeds ranging from 800 to 1,200 revolutions per minute, and to prevent the attendants lifting the cover over the beater, or the panel door at the front of the beater, whilst the machine is running, also to make it impossible to start the machine before the cover is turned down into its proper position, the locking apparatus as illustrated, is applied; Fig. 5, Plate 11, shows the cover and door closed, Fig. 6 shows them open. The locking apparatus consists of a bolt and connections, and to release the cover and door, the bolt is pushed into a corresponding hole in the flanged pulley on the beater shaft, and thus prevents the pulley and the beater shaft revolving. Before the pulley can be released the bolt must be slid in the opposite direction, where it enters corresponding holes in the end of the beater cover and in the lever attached to the panel door.

The train of wheels connected with the calender rollers may be protected by ground and glazed cast-iron guards as shown in Figs. 5 and 6, and the cage wheels may also have polished cast-iron guards as shown. These cage wheels run at a slow rate and are not especially dangerous; and although the doors to the draft flues are immediately behind, and should be readily accessible, some managers prefer to fix by screws sheet-iron plates to the extra guard so as to cover the arms of the cage wheels as shown.

Some deem it necessary to guard even the ends and sides of pulleys on the quick running shafts such as the beater shaft, by means of wrought-iron fencing, but in these cases this is usually provided at the mill and may be bolted to the sides of the machines. Illustrations of such guards are however shown on Figs. 2 and 3.

The next machine in the series of cotton spinning machinery——the Carding Engine—has all its revolving parts well guarded. The licker-in, the cylinder, and the doffer, are covered with bright sheet-iron or steel, screwed down to the sides. The bevel wheel and pinion on one end of the licker-in and side shaft run slowly, but may be guarded by a complete polished cast-iron cover, as shown on Fig. 7, Plate 12, or by a partial guard only, as shown on Fig. 8;

the former is, however, considered by some to be in the way and an inconvenience to the Strippers and Grinders, whilst the latter does not interfere with the convenience of the attendants. On the opposite end of this shaft the pair of bevels on the doffer shaft and the side shaft are covered with a complete guard as shown on Fig. 9. On the other end of the doffer shaft the large spur-wheel and pinion may be and are frequently guarded, as shown on Fig. 10. It is however at times convenient for the workpeople to be able to turn the doffer slowly by hand. Consequently, the plate wheel and complete guard would in such a case be an inconvenience.

A number of Carding Engines are usually placed in line, each driven by a strap from the main shaft, the passage between one Carding Engine and another being generally from 9 inches to 18 inches, according to the space at disposal and other circumstances. In England the passages between the Cards are left open, but in some countries a locked bar is placed in front as well as at the back of each passage, to prevent the workpeople from passing between the Cards whilst at work. Where such bars are in use, the application of the strap fork arrangement, as shown by Fig. 11, will enable the workpeople to stop a Card from either the front, middle, or back of the machine.

Ordinarily, the Drawing Frame follows the Carding Engine, and is usually provided with polished cast-iron hinged covers, which completely guard the draft wheels and other toothed gearing. When desired, a locking apparatus can be applied to these guards to prevent the attendants starting the machine whilst the covers or guards are lifted, or lifting the guards whilst the machine is at work. These covers are shown locked in position on Fig. 12, Plate 13, and as lifted out of the way when the machine is stopped, in Fig. 13. The illustrations also show the connection between the locking apparatus and the strap fork. Three heads of Drawing Frames are often connected by an under driving shaft the full length of the three heads and about a foot from the floor. This shaft, which is generally covered in the passages only, is now frequently encased in a tube from end to end, and pulleys of the plate or box pattern are used instead of those with arms.

The Slubbing, Intermediate, and Roving Frames, have the skew-gear wheels which drive the spindle and bobbin wheels completely guarded by sheet-iron plates. At the back of the machines the spur-wheels which drive the differential motion, and in the latest pattern of machines, the train of spur-wheels connected with the mechanism for regulating the twist, are enclosed by wrought-iron hinged doors. These doors, as in the cases previously referred to, have a locking apparatus which is connected with the strap fork, and so arranged that they cannot be opened whilst the strap is on the fast pulley, nor can the machine be set to work whilst the doors are open. This locking arrangement is of special advantage to frames of this class, making it impossible for an attendant, standing at the front or spindle side of the machine, to set the frame to work whilst the overlooker or other attendant, kneeling on the floor at the back, may be busy with his screw-keys altering or adjusting the gearing. Fig. 14, Plate 13, illustrates a machine with the doors closed, and Fig. 15 shows the doors open. Some mill-managers like to have guards for the pulleys, and driving strap at the end of Frames, and one way of doing this is by means of a cast-iron guard as shown by Fig. 16. Sometimes a sheet-iron box-guard is adopted, and this, standing about 5 feet high from the floor, surrounds the pulleys and the strap on all sides, as in Fig. 17.

The Self-acting Mule is the most difficult of textile machines to guard effectively. The revolving parts in the headstock near the centre of the Mule, with the rope pulleys running at high speeds, may be more or less guarded according to circumstances, as may also the middle drawing-out ropes and those at the out-ends of the carriages. There are also the wheels underneath the carriage bearers running on the slips or rails, as well as the stops on the faller shafts, to be taken into account. The carriage or traversing part is often about 40 yards long, more or less, and makes an outward and inward run some five or more times per minute. Fig. 20, Plate 14, shows a convenient arrangement of sheet-iron guard for the back of the headstock, to which it may be attached by bolts. In this guard are a couple of hinged doors with latches, which can be opened when required for convenience in oiling the mechanism at the back of the headstock. At the upper part a semi-circular guard covers the three-grooved rim pulleys as well as the ropes.

Fig. 18, Plate 14, shows guards over the rope pulleys on the tail piece of headstock, also a portion of a guard over the teeth of the quadrant pinion and the quadrant.

Fig. 19 shows these rope pulleys when unguarded.

Fig. 21 shows a guard to the middle drawing-out scroll on the back-shaft with its accompanying ropes.

Fig. 22, Plate 15, shows a guard over the pulley on the floor, over which the middle drawing-out band passes.

An improved guard to drawing-out scroll on the end of the back-shaft is shown in Fig. 23, and a guard to cover the carrier pulley on the out-end framing is shown in Fig. 24.

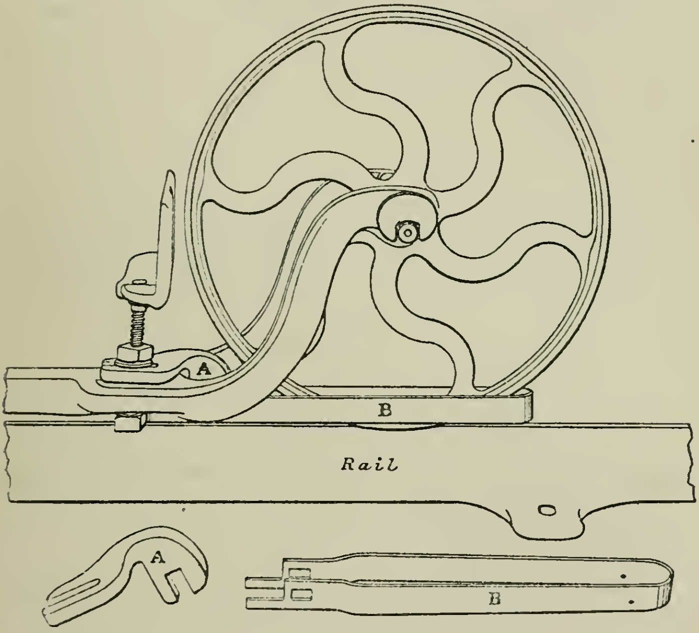
The "stop," which is mounted on the front or winding faller, is shown in Fig. 25; and with reference to this it may be mentioned, that the minders have a habit of resting their hands on the counterfaller shaft when following the inward run of the carriage, and at times forget that if their hands happen to be under the stop it will in coming down upon the counter-faller crush their fingers. This stop is now cast with a radial protecting piece in front as illustrated, which prevents the minder and the piecer from inadvertently putting their hands or fingers underneath the stop.

The wheels of carriage bearers, which run on rails at regular distances to support the mule carriages, are provided with guards to push anything off the rail in the running out and in of the carriage, thus preventing the foot being caught should it inadvertently be resting on the slip or rail. An illustration of this is shown in Fig. 26 (page 229).

Further description of guards for textile machinery would lengthen this Paper unduly; it may however be remarked that in Looms it is advisable to guard the ingoing side of the tappet wheels, and to take care that there are no projecting set-screw heads on revolving shafts. Revolving projecting set-screws on outside parts should wherever possible be avoided in all machines, unless guarded in an efficient manner. The shuttle race in Looms should be provided with an efficient shuttle-guard to prevent the shuttles being accidentally thrown out of the shed of the Loom, to the great danger of the workpeople. There are many inventions and devices for this object. The pattern shown in the illustration, Fig. 27, Plate 15, fixed to the hand top of the Loom, is well suited for the purpose. As a rule weavers do not like shuttle guards, as they interfere with the facilities for repairing broken warp threads.

FIG. 26.

Foot-Guard to Wheel of Carriage Bearer. Self-Acting Mule.



Reference in this Paper has been made specially to machines used in the cotton trade, and about these and the processes employed by different textile manufacturers, it may be said that they are to a certain extent uniform in character and mode of working. In the woollen and worsted trades there is greater latitude and variety in the machines employed; these the author does not at present touch upon, but merely remarks that where practicable it is desirable that care should be taken to guard the working parts of such textile machinery.

The subject is illustrated by Plates 10 to 17 and 1 Fig. in letterpress.

(*For Discussion, see page* 248.)

PROTECTION OF LIFT-SHAFTS, AND SAFETY DEVICES IN CONNECTION WITH LIFT-DOORS AND CONTROLLING GEAR.

By Mr. HENRY C. WALKER, *Member*, of London.

The subject which the author has been invited to open up for consideration is an important one. The present age is one of advance, accelerated speed, enlarged ideas, and accomplished facts where dreams only existed; and as the locomotive has supplanted the stage coach and carried a larger number of people a greater distance, so the lift today enables the buildings of several storeys to be built on a smaller area than otherwise would be possible, as an increased number of persons can gather together to do business, and a greater quantity of goods stored to meet growing demands.

In view of the vast number of passengers and the enormous quantities of merchandise carried by lifts, the number of accidents (so called "lift accidents") are exceedingly few and compare most favourably with the number arising from any other form of conveyance. It will be found that the accidents which are actually brought about by the failure of the lift, or part of its mechanism, are of singularly rare occurrence; the great majority, both fatal and otherwise, are almost invariably the result of carelessness upon the part of the victims or of the lift attendants, the larger proportion being through the insufficient protection of the lift shaft, the doors of which are frequently not properly secured, or are left entirely open. If every house, factory, or block of offices were built under one code of rules, and every entrance to a lift controlled by a fixed design, it would be easy to invent some device that would be applicable to all, and so avoid accident. As this is not so, means and devices whereby such mishaps can be avoided, or at any rate reduced to a minimum, form the subject-matter of this Paper.

It is not possible within its limits to describe all the numerous schemes designed to meet the many varying conditions of the problem, and as it is also obviously impossible to produce one uniform mechanism which shall meet all cases and requirements, the author will consider those most frequently to be dealt with, and what form of safety appliance is best to adopt in each case.

Power lifts, that is to say lifts driven by belts from shafting, as a rule are not very fast moving, and arrangements can be adopted that cannot be satisfactorily applied to fast running lifts; perhaps where height can be had there is no better form of entrance gate or door than that known as the "sliding shutter"; it should be provided with catches, the said catches being acted on by the cage, so that the gate cannot be thrown up or opened, unless the cage is nearly level with the floor. At this position the cage automatically trips the catch, and the gate is free to be opened and lodged on another catch, which in its turn is tripped when the cage ascends or descends and the gate is arranged to close automatically by its own gravity. The gates on the top and bottom floors can readily be made to open and close by the movement of the cage, but at the intermediate floors should be opened by hand, and closed and locked automatically. The last described arrangement of doors and gates is also suitable for hydraulic, electric, or other warehouse lifts.

With hinged doors or gates to open or close automatically (and many schemes have been devised to accomplish this), there is the danger of any one who might be standing at the opening being thrown into the lift-shaft, unless the device included an arrangement to ensure that the cage cannot be started till all the doors are locked or closed. Without this it would be possible to start the lift from another floor, when the automatic closing might be converted into the cause of danger; this to some extent depends upon the position of the starting rope, for instance, if the starting rope passes through the interior of the cage so that it cannot be reached excepting from the inside thereof, it involves someone always travelling in the cage to work the lift; on the other hand, if it be so placed that it can be reached from any floor, there is the danger of the lift being started by someone not knowing it is in use at a certain floor.

To make this arrangement perfectly safe therefore, some means of locking the starting rope should be employed; a treadle in the cage is not allowable unless someone is always in the cage, a screw or clip to fix the rope would be safe and effective, but it is impossible to ensure that it should always be used. A bar or lever arranged to obstruct the entrance to the cage when down, and when up to grip the starting rope would be preferable, so that the lift cannot be started again, until the bar is down and across the opening of the cage.

For ordinary warehouse purposes where sliding doors can be used, it is perhaps difficult to suggest a safer arrangement than that already indicated; but where hinged doors or collapsible gates, similar to the "Bostwick," are to be used, they cannot readily be made to close automatically, as it is obviously unsafe so to close a hinged door; and if left to be closed by hand there is the possibility of its not being properly fastened, and thus leading to an accident. This is a point which will be further considered in regard to the safest form of controlling the opening and closing of the entrance doors to passenger lifts.

The author now proposes to describe a lift with ideal entrance doors, locks, and controlling apparatus, without any regard to whether at the present time there is any apparatus extant that will fulfil the conditions described, or any scheme approaching this *beau ideal.* We will assume a lift worked by an attendant always in the cage, as at hotels, flats, offices, etc. Before the lift can be started, all the entrance doors must be closed and fastened, so that they cannot be opened whilst the cage is moving; on the car arriving at the floor level where it is desired to alight, this particular door should be free to open. On the door being opened, the means of starting the lift should be locked, so that it cannot be moved whilst the door remains open, and should only be released on the door being closed and locked. It remains to be decided how many and what are the operations that should be performed automatically, and what should be left to the attendant to do by hand in an ideal lift, for even if the whole of the operations are made automatic, it is a question whether it is necessary to spare the attendant all trouble in trying to eliminate all possibility of accident, by adding too many complications in additional safety devices.

The attendant having entered the lift closes the door or doors; this should not be done automatically, though possible to do so; it is easy to show that the door closed by any force other than the hand might cause injury. The door therefore being pulled to, locks itself, and at the same time releases the starting gear, which was previously locked by the opening of the door. The ideal starting gear would be a small lever, easily manipulated, the movement of the lift obeying exactly that of the lever. Thus, when the lever is placed in mid position the lift is to be at rest, but when inclined to the right or the left to start the lift up or down as the case may be, to commence slowly and gradually, to increase in speed as the lever is inclined more and more, until the maximum speed is attained. The reverse action is to take place in stopping the lift, the attendant thus having complete control of the speed could also stop the lift instantly in case of emergency, and could often prevent what might otherwise cause serious accident. Arriving at the floor at which it is wished to alight, the attendant, having stopped it level with the floor by means of his lever, proceeds to throw up a catch which unlocks the door, and at the same time locks the starting gear; he now pushes open the door and the passengers are free to leave the lift, which cannot be moved away until the door is again pulled to, when the catch automatically falling into its normal position locks the door, and at the same time releases the starting apparatus.

The requirements for safety of the lift openings are as follows:—

1st. It should be impossible to open the door at any particular floor, unless the cage is about level with that floor, or by special key for the purpose of repairs, cleaning, &c.

2nd. When the door is open, it should be impossible to move the cage away from that particular floor, until the door is again closed and fastened.

3rd. It should be impossible to open more than one door at the same time.

In cases where it is necessary to bring the empty cage to any floor, if these conditions are to be complied with, it is necessary to provide means for controlling the lift from any floor as well as from the interior of the cage.

The various devices and inventions to attain these ends, and which the author will now bring to notice, can conveniently be divided into two classes.

1st. Mechanical appliances, under which class will come every apparatus or device actuated either by the movement of the lift itself or put into action by the lift operators.

2nd. Power appliances. Under this class are included those which are worked by or brought into action either entirely or in part by means of some motive power, such as water-pressure or electric current.

A lift controlling-gear was designed by Mr. E. B. Ellington and fitted in some flats at Kensington, and which allows the lift to be started only when the doors are closed; and the door at which it is desired to alight can only be opened when the lift is at the particular floor; this gear is entirely mechanical.

Fig. 1, Plate 18, shows a simple device which will prevent anyone falling down a lift shaft. This consists of a number of guards or trays approximately fitting the lift shaft, suspended from the bottom of the lift cage by means of chains, their distance apart corresponding to the height of the respective floors; on the top of the cage is another set of these guards; as the cage descends it leaves one of these guards at each floor level. Each guard is provided with stops fixed in a different position, so that one only is left at each floor. As the cage ascends the top guards are packed up in turn, as also the lower ones, which as well as the top set are guided to keep them in proper position; they are usually constructed of strong diamond mesh wirework fixed in suitable iron frames. The guards are, however, of limited application; they would not be suitable for a quick-running lift, and have other obvious defects, as they could not well be fitted in a staircase, and take considerable extra power.

Figs. 2 and 3, Plate 18, show an arrangement of automatic lift gates. These are designed to ensure a gate at each floor of a lift-well being unlocked when the cage or car arrives opposite the gate, the latter being automatically closed and locked on the cage moving away, in either direction, so that the gate cannot be accidentally left open or opened by hand, when the cage is not at that floor. For this purpose the gate, which is suitably guided, is fitted with stops 1 and 2 at the bottom and top of its frame. The gate is nearly counterbalanced, being connected to weights by chains passing over guide sheaves; these weights are somewhat less than the weight of the gate, and in order to make more sure of the gate falling by gravity, but to minimise the shock of the gate, additional counterweights are picked up as the gate descends, causing it to slow up at end of its stroke and close without undue shock or noise. The cage is fitted with suitable strikers, which on the rise or descent of the cage acts upon a locking or releasing gear and limits movement of catch in one direction. The rising gate in passing the catch C depresses same to the right, until the stop 1 on bottom of gate has passed, and allows spring P to pull catch C into position to support gate and keep same at required height above floor level.

On the cage moving away, the top arm of lever L together with the catch C are pulled to the right, releasing the gate by spring P, and the lower arm of lever L passes through slot M in channel guide, allowing the gate to descend. The gate in descending pushes lower end of lever L aside until stops 1 and 2 have passed it; the lever L is then pulled by spring into the locking position forming a lock by engaging with stop 2, and so preventing any one raising the gate unless the car is opposite. These gates have proved to be a very efficient safeguard; they were designed chiefly to meet the case of warehouse or goods lifts when a simple and not too expensive safeguard is required, and they work quite satisfactorily when fitted to any type of lift working at either high or low speeds.

Plate 19 shows an automatic gate arrangement, specially suitable for goods hoists, and it can be fixed where there is little head-room. The gate is divided in two portions sliding vertically in opposite directions, Fig. 4, and is opened and closed by tappets, Fig. 6, on lift cage as the latter approaches and leaves the floor; so long as the lift is run at a low speed the noise through continued opening and shutting would not be excessive.

The foregoing devices being all of the mechanical class, the author will now draw attention to a few devices for effecting similar objects, but which are put in operation by the aid of power.

The Hollins-Amendt locking gear, Fig. 7, Plate 20, for lifts consists primarily of a rope-gripper fixed outside or inside the lift cage, and can be put in action to lock starting rope by the lift attendant. The entrance doors on each landing are fitted with special locks, which, together with the before-mentioned gripper, are under electrical control, the necessary current being furnished by an ordinary battery, say of Leclanché cells. The door-locks are so arranged that they cannot be unfastened unless the starting rope is gripped.

On arriving at any floor at which the passengers wish to alight, the lift operator first puts the gripper into action by means of a rope-pull, lever or treadle; when this is done, the door-catch or lock is free to be thrown back and the door opened, but the action of unfastening the door automatically prevents the gripper itself being unlocked, the arrangement of the electric circuit being such that the gripper cannot free the starting rope until the door is again closed and locked. When this is done, the operator by pressing an electric push-button fixed inside the cage frees the catch on gripper and releases the starting rope.

This system provides the following elements of safety:—The lift cannot be started unless all doors are properly closed and fastened. No door can be opened unless the lift cage is opposite same. The starting rope must be locked before the door can be opened. This is one of the best arrangements for protection of lift openings.

Fig. 8, Plate 20, is a diagram of an arrangement of Hydraulic Semaphore Safety Arms for lifts. It shows each opening to the lift fitted with an arm, which bars the passage way into the lift-well at all times other than when the cage is at rest at that particular floor when the arm is automatically unlocked and raised. In the diagram two floors only are shown. In the lower floor the lift being away the arm E is shown protecting the well-hole, and locked by the catch F. In the upper floor the arm E^1 is shown raised and the catch F^1 is unlocked. These arms work entirely automatically, and do not open when the cage passes a floor without stopping, but only when the cage stops at any floor. The arm at that floor is unlocked by the cage and automatically opens.

Electrical arrangements are used in flats or other places. The merit of simplicity combined with cheapness is claimed for that designed by Mr. E. C. de Segundo for passenger lifts where the traffic is not sufficiently great to warrant the employment of a permanent attendant, the lift being left in charge of a boy or of the hall porter who may or may not be available when a passenger wishes to use the lift, in which case the lift is generally operated by the passenger himself. This device consists of an electrically controlled shutter, the normal position of which is over the keyhole by which the lift door is opened. When the lift is at rest, any one shutter can be pushed aside and the key inserted. The action of pushing the shutter aside and opening the door, however, automatically locks all the other shutters on the remaining doors on each floor, so that it is impossible for any one else to have access to the lift. The action of putting the lift in motion also automatically locks the shutters on all the doors, so that while the lift is in motion no one can open any of the doors from the outside. All doors are supposed to be fitted with self-closing springs, but should a spring have broken and a door remain open, all the other shutters will be locked. A bell-push, which is fitted at the side of each door, is so connected up that on pressing it on any floor, a bell will ring on the floor upon which the door is unfastened, so enabling the unclosed door to be at once detected. When the lift is in motion all shutters are locked, and pressure of any bell-push will ring a bell in the lift indicating the floor upon which it is required.

Fig. 9, Plate 21, shows an arrangement of electric gear for locking controlling-gear and gates for lifts. For this purpose an electric circuit is carried up and down the lift shaft, and controlled by switches S, usually forming part of the door catches or locks. Forming part of this circuit is a flexible cable connected to a gate-catch or switch in cage, this gate being usually of the collapsible type. In the circuit which is supplied with electric current from mains or from batteries is placed a solenoid M. This solenoid has a stop H fixed to the bottom end of its core-bar and which engages with a notch or gap in the rim of drum D, which latter is used for operating starting gear and to which the controlling rope is fixed. When all the doors are shut and fastened, the circuit is completed and the solenoid M is energized and withdraws stop H from notch in drum, and the lift is free to be moved.

On the arrival of the lift at a floor, the attendant stops it in the usual manner, and immediately he releases the catch on the cage gate the electric circuit is broken, and stop H immediately falls again into locking position, effectually preventing the lift being moved, unless all doors are shut and fastened. The lift-well doors cannot be opened from the outside, except with a special emergency key. This arrangement of the gear is more suitable for electric or power-driven lifts than for hydraulic lifts; in the latter case a rigidly locked starting gear may cause trouble, should the controlling valve become leaky, a contingency not altogether unknown to makers and users of this class of lift. In such lifts it is preferable to fix the solenoid on the cage, and in this case the hand-rope is seized by a gripper actuated by the solenoid, when the latter is energized or the movement of the hand-rope is prevented by means of sliding-stop plates closing on hand-rope and between stops fixed to hand-rope. The whole of the locking gear acts automatically, the person operating the lift only pulling the starting rope and opening the doors in the ordinary way.

It should also be noted that in the event of any failure of the circuit or the connections by accident, on the forcing open of any of the doors it would prevent the running of the lift until the failure was made good again, which is a guarantee for its always being kept in a good and safe working condition. Also it can be readily fitted to any existing lift, and is not unsightly.

Electric lifts, made to work without an attendant, are fitted with a push-button system, in which case the gates or entrance doors are automatically locked.

There is a set of pushes in the cage; by pushing one of these the lift starts and stops at the desired floor; but it will not start unless all the entrance doors are shut and fastened, nor can a door be opened on any floor until the car is at rest at that floor. The lift can be called from any floor by simply pressing the button of that floor.

Mr. H. Cecil Walker has invented an arrangement of service or parcels lift, so that any shutter thrown open while the lift is in motion stops the lift, and it cannot be started so long as any shutter is open in connection with this. There are variations that make it completely under control and ensure the almost complete protection against accident.

The subject is illustrated by Plates 18 to 21.

(*For Discussion, see page* 248.)

GUARDING MACHINE TOOLS.

By Mr. W. H. JOHNSON, of Manchester.

The Workman's Compensation Act of 1899, together with the exacting requirements of factory inspectors, have compelled engineers to pay more attention to the subject of Guarding Machine Tools.

Guards are made of various materials, as :—

(I.) Timber.
(II.) Cast metal, usually iron.
(III.) Sheet metal.
(IV.) Hoops, rods, and bars of metal.
(V.) Wire work.

Before dealing with the qualifications of these materials for guards and the various ways of applying them so as to protect machinery, it may be well to consider what conditions a perfect guard must fulfil.

1st. It must fence the tool efficiently; in other words, it must protect workmen from all dangerous moving parts of the machine, and thus satisfy the factory inspector.

2nd. If possible, it must be attached to or near the tool ; as if loose, a careless workman will remove it and not replace it, so that it ceases to act as a guard.

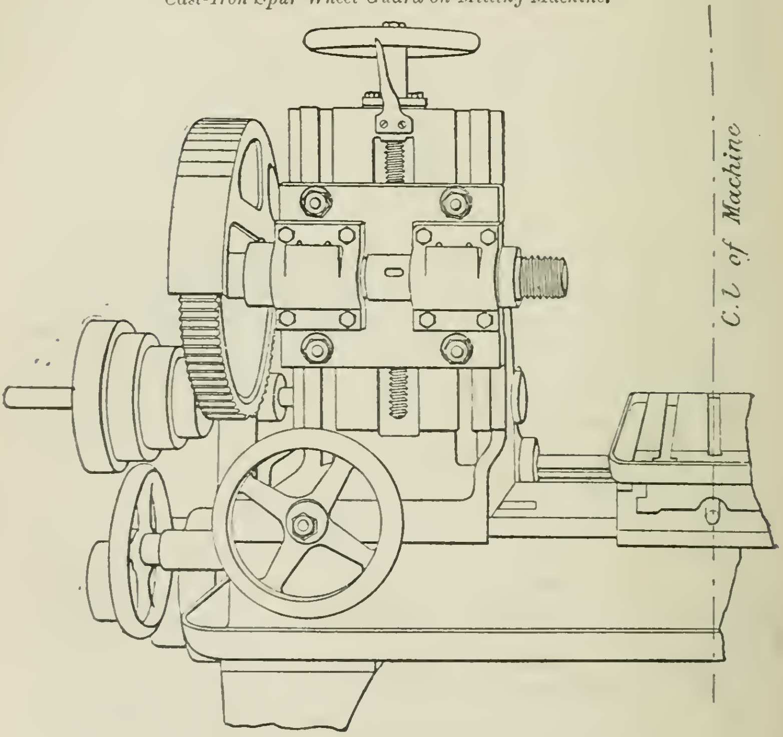
3rd. At the same time it must be so constructed that a workman can move it on one side to oil the machine, adjust a belt or change wheels, and bring it back into position with a minimum of time and trouble.

4th. While sufficiently strong, it must not be heavy or clumsy.

5th. The guard must not prevent the operator seeing through it, unless it is intended to act as a cover to keep chips of metal out.

Fig. 1.

Cast-Iron Spur-Wheel Guard on Milling Machine.



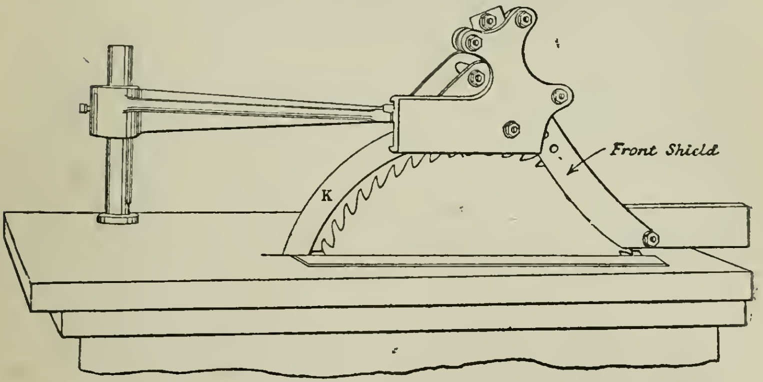
Keeping in mind these five conditions which a perfect guard must fulfil, the author will now proceed to consider how far guards at present in common use on machine tools comply with or violate them, and what materials and what designs are best suited for various tools.

(I.) *Timber*, the first material named of which guards are made, absorbs oil, shrinks and soon falls to pieces, is easily broken, and does not conform with any of the preceding rules; hence it is so unsuited for the rough usage of an engineering shop that it need not be further considered.

(II.) *Cast Iron*, the second material in the list, is probably the one in most general use. Tool makers commonly fix a light casting to cover the exposed parts of spur or other toothed wheels in the tools they sell. These guards, an example of which is shown in Fig. 1, are neat, easily fixed, and if a large number are wanted they are cheap, as the quantity covers the expense of making the pattern to cast from. The casting affords ample protection, is fixed and is strong, thus conforming to the first, second, and fourth conditions.

Fig. 2.

Cast-Iron Guard to Circular Saw.



Circular-saw guards are so numerous that they may be numbered by the dozen; the one illustrated, Fig. 2, composed chiefly of cast-iron and made by Messrs. Asa Lees and Co., of Oldham, is a good example, more especially as it is fitted with a riving knife K, an indispensable adjunct to any saw guard. As it has up to now been found impossible to design a saw guard which affords efficient protection under all circumstances, this guard only partially conforms to the first condition laid down, but it fairly complies with the remaining four.

(III.) *Sheet Metal.*—If the wheels to be fenced are large, a casting becomes too heavy, and is much better replaced by a guard made of sheet metal. For this purpose there is no material to compare with planished steel sheets strengthened at the edge by light iron rods of square section. In skilled hands such uncommonly smart-looking guards can be turned out of this material, that they will not only guard the tool, but set it off in a way no cast-iron guard will. A planished steel guard is lighter than cast-iron, and not liable to break in transit by rail or sea, both no mean advantages.

FIG. 20. *Guard in Halves for Bevel Wheels.*
(*See Figs.* 3 *and* 4, *Plate* 22.)

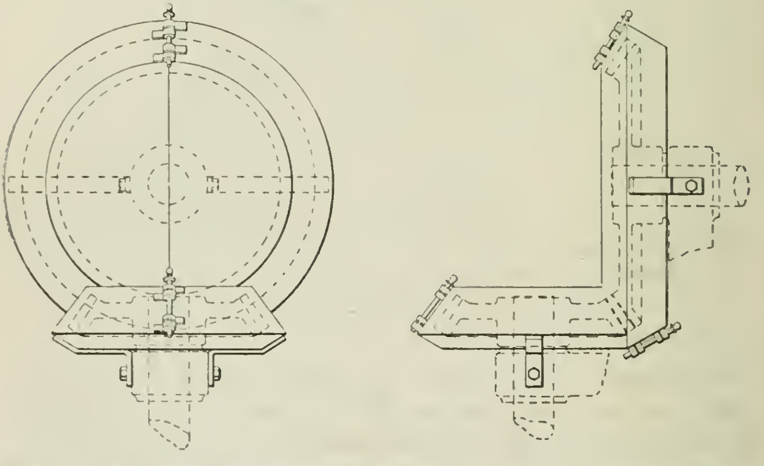


Fig. 3, Plate 22, shows two drilling machines with the bevel wheels of the drill spindle protected, with planished sheet-steel guards. They are made in halves and are fixed by bolts to the side of the drill, making a good fence and stopping the oil from being thrown from the gears on to the operator's face. Fig. 14, Plate 24, shows a sensitive drill, and Fig. 6, Plate 22, a sliding surfacing lathe, with planished sheet-steel guards, the construction and fixing of which can be easily traced from the photographs. Fig. 4 shows a horizontal and vertical main driving shaft, coupled together by bevel wheels, with protection similar to the drilling machine before mentioned, but of much larger dimensions.

(IV.) *Hoops, Rods, and Bars of Metal.*—With regard to the fourth class of materials, "Hoops, Rods, and Bars of Metal," stout hoops are often used to fence spur wheels, and rods supported by pillars form a partially effective fence where ample space is at command. A flat iron bar makes a capital guard for the periphery of grindstones or emery wheels, Fig. 5. It prevents the workman being trapped, and, should the stone break, stops the pieces from flying away.

(V.) *Wire Work*, the last material on the list, has many advantages. It is light, easily fixed, does not obstruct the light or the view, and can be made cheaply. Fig. 7, Plate 23, shows the back- and carriage-gear of a radial arm drill protected by inexpensive wire guards. The spur wheels of the cone pulleys can be oiled or even cleaned without removing the guards, also the operator and shop foreman can see that they are kept clean, likewise without removing the guard. This is impossible in any other material. The bevel gears of the drill spindle and feed gears on the horizontal shaft are protected as shown. The mesh of these guards is made close, so that the operator's finger cannot go through.

Figs. 8 and 9, Plate 23, show a horizontal shaft and coupling protected by a wire guard first in position and again open for oiling, and giving ample room for the free use of the plumb-bob and spirit-level while lining up the shaft. Figs. 10 and 11 show a stout wire guard protecting a driving belt. The guard is fixed to the washer A, which moves freely on the pillar. The lower face of the washer is furnished with a V-shaped projection, which engages in either of the V-shaped slots in the washer B, according as the guard is open or shut. The washer is firmly fixed to the pillar. If a movable guard of the shape shown in Fig. 12 be used, conditions two and three are violated, while the guard in Figs. 10 and 11 conforms to all five conditions, and has the following special advantages.

(*a*) It offers no trap when open, as it moves right out of the way.

(*b*) There is more ground space on which work can be laid.

(*c*) Should a workman let the tool he is grinding fall (quite a common occurrence), he will not have to remove the guard to pick it up, and thereby run the risk of being hurt by the unfenced belt or pulley.

Figs. 13, 14, and 15, Plate 24, show a sensitive drill in the author's works, which the factory inspector ordered to be fenced. A wire worker was called in, and made the guard shown in Fig. 13, which is given as an example of what a guard should not be, but what one may expect if the design of a guard be left to an unskilled man, instead of calling in an expert who combines the knowledge of the tool with skill as a wire worker. It violates every condition that a perfect guard should contain. It is clumsy, being simply placed on the floor and not attached to the machine, is shaky and can be easily knocked over. It has to be lifted bodily out of the way for oiling, and the door at the foot, which was made to allow the operator to alter his belt, opens up the wrong way and thrusts the workman from what he desires to do, and forms a dangerous trap, so that the drill would be safer without the guard than with it. Figs. 14 and 15 show the same drill, closed and open, fitted with guards, that have been pronounced perfect by more than one factory inspector. The planished sheet guards on the head of the machine have been noticed under the heading of sheet metal guards; it would be as well to mention that the fencing is so efficient, that it is next to impossible for anyone to get a finger trapped between the revolving parts or be struck by the moving belt. The wire work guard is fitted with four hook-shaped clips, which allow it to be moved round the two supports, thus not only enabling the operator to attend to the oiling and belting with perfect freedom, but allow him to move the guard to any position and get the table on either side of the drill, as is often required for awkward pieces of work, the various changes being made with the least possible amount of labour.

The efficient fencing of the change wheels, and feed mechanism of large sliding, surfacing, and screw-cutting lathes is a matter which factory inspectors are beginning to insist on, but at the same time presents many difficulties. Thus a guard made to fence the largest geared wheels will occupy too much shop room when small wheels are in use. Further, the guard must let the turner see the train of wheels he has in gear, and yet must open to allow him to change them. Figs. 16 and 17 show a guard designed to overcome these difficulties. It is made in two halves hinged to a fixed central pillar. Either half will open and swing clear, and admit of lateral extension along the supports A, A, and can be secured in any position by the thumb-screws B, B. The guard when attached to the lathe is similar in appearance to the one shown in Fig. 6, but is a much improved pattern.

Figs. 18 and 19 show a well-known capstan lathe with the feed mechanism guarded. It will be seen from Fig. 18, showing the guard closed, that it is impossible for any one to get caught by the belts. The open view, Fig. 19, also shows the guard is not in the way when the worker wishes to change his feed, &c. Being a fixture to the floor, it never becomes displaced. It can be opened or closed with the minimum of labour and time, without removing the stock from the machine, and the author thinks may be safely named a perfect guard. This style would be admirably adapted for lathes up to say 8-inch, 10-inch or even 12-inch centres as a fence for change wheels.

The subject is illustrated by Plates 22 to 26 and 4 Figs. in letterpress.

(*For Discussion, see page* 248.)

Discussion on 21st March 1902.

The PRESIDENT moved that a hearty vote of thanks be accorded to the authors of these Papers for their communications, which was carried with acclamation.

He pointed out that one special object the Council had in bringing forward the Papers for discussion simultaneously was to obtain expressions of opinion from some of the factory inspectors as to what they considered really efficient guards of engines and machines. As he had mentioned at a previous meeting, when announcing the Papers, a great deal of money was constantly being wasted by putting up guards which did not satisfy factory inspectors, and that not from any wish on the part of those who provided the guards to avoid their responsibility in any way, but simply because there was a great variation in the practice of different inspectors, and very great differences of opinion existed as to how guards should be designed and fixed. It was thought that, by discussing together the four Papers dealing with the different classes of machinery, it would be possible to get expressions of opinion which would be very useful to the owners and users of such machinery, and which would also facilitate the work of the factory inspectors.

Mr. C. C. W. HOARE, H.M. Inspector of Factories, confined his remarks to the Paper by Mr. Walker dealing with lifts, or, what was a more familiar word to him, hoists. The Paper on the whole was excellent, although there were one or two points in which he should venture to differ from him, mostly with reference to the suggestions that the closing of the doors of hoists should not be done automatically. He took exception to that, because the difficulties inspectors had in dealing with hoists were that it was not possible to make workpeople careful, and therefore an automatic closing of the doors was the very thing required. It might be left to the skill of the man to open the door when he was going to use the hoist, but if it was left to his skill to close it, he would go away and forget it.

He did not propose to make any remarks on the subject of lifts or hoists in connection with hotels, or places of that description, as they did not come under his supervision, but would confine himself to the hoists of factories and warehouses. The difficulty the factory inspector had to contend with was that he found hoists not only of a most modern description, but some of a very ancient description, and he could not well order the owner of the hoist to remove it or put in something more modern; he therefore had to strive to make the existing hoist safe, and it was upon that the disputes arose. The inspector had his ideas of safety, but unless he was prepared to take the case into Court when the proprietor differed, the matter had to be argued out. Many hoists were used for purposes of carrying goods, and were very roughly treated, and any plan of self-acting catches was apt to get out of order from wear and tear, and become worse than if there were none to be relied upon, as they betrayed the user into believing that the catches were all right when they were not. As an instance, he mentioned that the doors of a hoist were supposed to be locked by a spring lock, and three of those locks got out of order. He was travelling in the hoist, and as it went by one of the doors, the door was pulled open and a woman jumped in without waiting for the hoist to stop.

Again, those who used the hoists would not only use them, but in many instances abuse them, and if a catch did not work quite to their satisfaction it would very soon get out of order,—of course accidentally! With reference to locked doors, in one instance he ordered, in a large mill in the town of Oldham, the doors to be taken away from the hoists, as they were not satisfactory, owing to the fact that a lot of children were working there, and locked doors to be put in their place. The new doors were 5 feet high, and only those who were allowed to use the hoists had keys. Unfortunately the carpenter, who wished to make a good job of it, put on rather a flat top, above 5 inches wide. He (Mr. Hoare) thought the hoist was well enough fenced to prevent the children abusing it, but to his astonishment he found the children were more like cats than anything else, for shortly after the doors were put up he had a report that a child had been killed at the bottom of the well. When

(Mr. C. C. W. Hoare.)

he visited the place no one could tell him anything that happened, so he called some children out of the floor on which the accident had occurred, and, having sent the manager away, said: "Now the manager has gone, you need not mind telling me all about it." They looked at one another, and then a small boy held up his hand and said, "On Saturday morning little Tommy offered me a halfpenny if I would do the same as he did." I asked what little Tommy did, and the child replied that he scrambled on the top of the door, jumped forward, caught the rope, and slid to the bottom. On the unfortunate occasion he no doubt missed the rope, and was killed. It was very evident that he had gone down before several times.

Employers were very often fond of studying economy, and he did not blame them. There was one new hoist in another mill in Oldham as to which he made a good many suggestions with regard to the fencing, and he was told that a bar would be placed across it. He said, however, that he would not assent to a bar, and if the proprietors desired, he was prepared to carry the case into Court on the bar matter. Shortly afterwards he received a report of an accident, and on going to the mill found a good square solid oak bar, and on that bar were the indentations of the teeth of a woman, indentations nearly $\frac{1}{16}$th inch deep, where she had been caught on the bar in looking over to see where the cage was. The woman's life was saved in a most wonderful way, probably because she had a rather thick skull. That lesson taught him not to trust people after giving orders, but to follow up the orders and see that they were carried out. But for the fact that the man in the hoist saw the woman's petticoats and reversed the hoist, she would have been killed. Several had been killed in that way in his experience. In another case the manager was looking over the door when the hoist, a silent one, came down and caught him by the head, and as his head was turned over the top of the door, he was scalped, but in his struggles he burst the door out of the jambs, and his life was thereby saved. It was possible to mention several instances where life had been lost owing to the same circumstances, and therefore he did not think that doors which were fixtures on the cage of the hoist were safe fencing. With reference to Mr. Walker's suggestion of the hoistman locking the door (page 234), a locking-gear was referred to, which whilst locking the door started the hoist. That was a dangerous thing to do, because, as the man was getting into the hoist and pulled the door to, he might unfortunately slip. At Colman's factory a man slipped in locking the door, and started the hoist at the same moment, and he was caught in the brick archway above and killed. Mr. Walker spoke of there being only a few hoist accidents. He wished he could agree with him; unfortunately he had had to investigate a great many, and many fatal ones.

Another objection to bars was that where there were children they would play about about near the hoists, and no bars were safe under those circumstances, because one child might push another, and they would shoot underneath the bar, and the bar would not save them. Within the last six weeks there was a place in London, where he objected to bars which were too near the hoists, and which he thought ought to be recessed; only the lower bar was recessed through a misunderstanding, and within three weeks a boy was caught on the top bar by the cage—fortunately not a very heavy cage—and he had a very nasty wound on his head, which had been healed by putting the boy on full wages since the accident happened, at his (Mr. Hoare's) suggestion. There was only one other point he wished to call attention to, and that was his idea of the secure fencing of a hoist; it did not at all agree with Mr. Walker's suggestions. His ideas were that the door framing the well should not be made to rise to open, but should sink into the floor, that the cage itself should shut and open the door as it came to the floor. If the hoist was coming downwards, the door would precede the bottom of the hoist by one foot, and by the time the cage was at the floor the door would be in the floor. Whether the cage went up or down, the moment it began to move away the door began to return to its place, and by that means the danger of the well began to be protected from the moment the cage left the floor. Those doors could be made so that they could only be acted on when the cage was at the floor. It was easy enough to do it when there was an attendant inside, but it was a little bit more difficult to do it from the outside. He believed, however, it was perfectly practicable.

Mr. W. F. IRELAND, H.M. Inspector of Factories, had listened to the Papers with real pleasure, and welcomed them, as everyone interested in the reduction of industrial accidents must welcome them, as a record of what could be done by engineers when they interested themselves in the matter. He was afraid, however, that all engineers did not take the same interest in the subject that was manifested by the authors of the Papers. Mr. Johnson stated (page 243) that tool makers commonly fixed a light casting to cover the exposed parts of spur or other toothed wheels in the tools they sold; but that was not his own experience, for with rare exceptions he found the tools were sold and delivered with the dangerous parts quite unguarded. Why that was so he could not understand, for the makers could fence those parts more cheaply, more neatly, and often more effectively than could be done by the purchaser of the machine; and he was convinced that systematic fencing of new machinery would not only tend gradually to reduce the number of machinery accidents, but would be also to the profit both of the maker and of the user. He had discussed the matter with several makers, and they generally stated, if they were inclined to fence their machinery, that they had to compete with makers who did not fence, and that the present cutting prices did not permit of this, without increasing the prices of the machines. But he had never yet spoken to a factory occupier on the subject, who had not expressed his willingness to pay more for a machine properly guarded than for one which was not guarded. They said it would save them a lot of trouble, and that they would have their machinery properly guarded from the very beginning. Many engineers seemed to think that the subject of fencing machinery was rather beneath their notice, and in engineering shops, of all places, guards were not infrequently found completely misplaced; for example, in the case of spur wheels, the outgoing side fenced instead of the ingoing side. Why that was so he could not understand, for engineers were naturally the best fitted for devising and fitting guards to machinery. Since the Workmen's Compensation Act had come into force many occupiers had recognised that it was more economical to fence their machinery than to leave it unfenced, and some, who before the Act came into force were always objecting to fence, now went out of their way to ask for suggestions as to how they could make their machinery safe.

Mr. Platt expressed the opinion (page 222) that guards did not increase the efficiency of the machine, but even in textile machinery he (Mr. Ireland) questioned whether that was the case. If the guard prevented accidents, it prevented the stoppages which would occur through an accident, and in the course of his Paper Mr. Platt had himself mentioned two or three instances where the guards themselves served other useful purposes. In wood-moulding machines, for instance, the operator's hand of necessity had to be very near knives, revolving at a very high rate of speed. The man in the ordinary course must devote a considerable amount of attention to keep his hands free from the knives, but if a proper guard was fitted to the machine that became unnecessary, and he was able to devote all his attention to the work he had on hand. He had recently visited a place where there were a number of power presses used for stamping tins, and where guards had been quite recently fitted. On questioning the manager, he was informed that since those guards had been fitted the production had been increased 12 per cent., and the manager expected, when the guards were perfected and the operators became more familiar with them, that the efficiency would be still further increased. Fig. 3, Plate 22, of Mr. Johnson's Paper was as good an illustration as could be obtained of "how to do it and how not to do it." The figure was a vertical drilling machine, and showed a pair of bevels beautifully guarded, but further down on the drill socket there was a projecting stud which should never be permitted to project in that way. He was glad to see that Mr. Platt drew attention to the danger of those things. He stated that care should be taken that there were no projecting set-screw heads on revolving shafts, and that revolving projecting set-screws on outside parts should, wherever possible, be avoided in all machines, unless guarded in an efficient manner. The use of a safety stud, or recessing the pin-head in the socket of the machine, and using a box key for screwing up, entirely removed the danger, although the operator when he wanted a set-pin would as likely as not pick up the one nearest to him, without any regard

(Mr. W. F. Ireland.)

as to whether it would be flush with the surface of the socket or project a couple of inches. The workman himself could do as much as the employer towards the reduction of accidents.

He was particularly pleased that the three authors who dealt with the fencing of machinery drew attention to the necessity of fencing circular shafts, for there was nothing more terrible in the injuries they could inflict or more erratic in their action, and there was no part of machinery as to the danger of which there was more ignorance amongst experienced engineers than in the case of a plain shaft. In his experience, more accidents of a very serious nature occurred with shafting than with any other part of machinery. What the limit of safety was, it was very difficult to say. He had heard of an accident only recently with a shaft of about 2 inches diameter running only at thirty revolutions a minute. A man was caught by the shaft, and another man who went to try and pull him off was also drawn in. That showed that the limit of safety was very low. He had known of people being caught by small shafts running at as low a speed as twelve or fifteen revolutions a minute. Practically all shafts which were at all accessible should be boxed in, and in the case of overhead shafting, where oiling had to be done while the shafting was in motion, it was advisable that for 2 feet 6 inches or so from the bearing the shaft should be covered in, or, at any rate, a safety ladder provided. It was more astonishing that there should remain that ignorance amongst engineers as to the dangers of shafting, because the danger was mentioned in text-books. Unwin, in his "Elements of Machine Design," said that all accessible shafting should be fenced in with covers of tin-plate. Fig. 5, Plate 22, in Mr. Johnson's Paper illustrated a type of guard for an emery wheel which he (Mr. Ireland) very often recommended, but as it was carried out in the drawing he thought it was faulty. The plate, as it was fixed on the machine, would hardly resist the force of the bursting of the wheel and confine the flying pieces. It was more usual in those guards to connect rigidly both ends of the plate; from the front end of the plate two rods, one on each side of the wheel, were carried down to the other end of the plate, making a rigid connection. He also thought more care should be exercised in fixing emery wheels. Last year he came in contact with two accidents through the bursting of emery wheels, one fatal and one not, both of which, in his opinion, were due to faulty wheels. In the fatal case, one side of the wheel was very uneven and slightly coned, and as the washer was quite flat, there would only be a small circle of contact near the centre of the wheel. If both the emery wheel and washer were regularly coned to fit each other, the arrangement would not only strengthen the wheel, but, in the event of a fracture, would tend to confine the pieces within the washer. He thought also it was very good practice, in starting, to run new emery wheels or new grindstones for the first time either in meal times or after work had been finished for the day. The other machinery being then off, the wheel could be run at a greater speed than usual, so that if there was any latent defect in the wheel, it would burst when there was no one near to be injured. The guards illustrated in Figs. 4 and 6, Plate 22, for the shafting on Plate 23 and for the belts in Fig. 10, Plate 23, and Fig. 14, Plate 24, were very good indeed, and the change-wheel guards were refreshing after some which he had seen in engineering shops. Over and over again, in speaking of the necessity of fencing change-wheels, attention had been drawn to the necessity of fitting a light guard, easily removable, for the purpose of allowing the change-wheels to be adjusted, but on return it was found that a heavy wrought-iron guard had been fitted, which a man had great difficulty in moving. Several nuts required to be unscrewed before the guard could be removed, and the natural result was that the guard was left off altogether. Guards such as were illustrated were more likely to be put on and kept in place. What was done by Mr. Platt's firm in fencing machines was an object lesson to manufacturers of other types of machinery, although to the practical engineer there seemed little necessity for some of the guards illustrated in the Paper.

Mr. Platt remarked (page 223) that more protection ought to be afforded to the employers against workpeople, who neglected to avail themselves of the provisions for safe-guarding provided by the

(Mr. W. F. Ireland.)

employers. The Factory Acts made such provision where the employer exerted due diligence in seeing that the law had been carried out. A workman, who was responsible for the guard being removed, could be proceeded against for the failure to maintain the proper fencing of the machine. In Mr. Marshall's Paper the guards used were rails. Where rails were provided as a fence for machinery they should be at least 15 or 18 inches from the fly-wheel or any part that had to be fenced. If the railing was any nearer, anyone falling on to the rail was liable to fall on to the fly-wheel itself. Single rails were objectionable, no matter for what purposes they were used, whether for a hoist or as a guard for an engine. Where one rail was provided, a person might often fall under the rail and so on to the part guarded. In any case a rail, in the position shown in Fig. 1 (page 212), could not serve as a guard for the cross-head guide. The only really effective guard was either a close wire or metal guard, such as was provided by some makers for their engines. Little mention had been made by Mr. Marshall about gas-engines; but gas- and oil-engines were rather more difficult to fence than steam-engines, because there was the necessity generally of turning the fly-wheel for starting. In a great many cases there was not sufficient space in the engine-room to enable a proper rail guard to be provided. In cases such as that, a good guard was a framing of wire netting hung on two uprights and balanced like a window-sash, but, in fitting such a guard, it was most essential that the uprights should be sufficiently far from the fly-wheel to enable the engine-driver to turn the fly-wheel with safety. That the subject of fencing was of the greatest importance was evident from the Chief Inspector's Annual Report. In 1900 there occurred 75,000 accidents in factories alone in the United Kingdom, and 25,000 of those were machinery accidents, 400 of which were fatal. A great proportion of them must have been due to lack of fencing of machinery.

The following classification from the same Report would be of interest to engineers:—

Machinery Accidents in the United Kingdom, 1900.

Machinery, &c.	Fatal.	Not Fatal.
Hoists	41	597
Shuttles	—	165
Cranes, &c.	82	1,914
Emery Wheels and Grindstones	2	449
Circular Saws	11	1,686
Miscellaneous Machinery	237	18,224
Cleaning Machinery in motion	6	1,630
Lathes	1	1,864
Power Presses	1	1,127
By machinery not moved by power	12	1,659

He thought it was very gratifying that the Council of such an Institution as that of the Mechanical Engineers should have taken up the question of fencing machinery. Engineers were best fitted to tackle the problem, and if the effect of the meeting was to induce more systematic and thorough fencing, the result would be not only a saving to the employers but to the country at large, and a substantial reduction in the number of those maimed and crippled by machinery accidents—a result which the Institution of Mechanical Engineers might well be proud of. [*See also page* 259.]

Mr. MARK ROBINSON, Member of Council, thought that no one could fail to see the value of the very practical suggestions contained in the Papers, but what was almost as striking was the evidently very small part of a very large subject which even those practical and detailed Papers covered. Without desiring to say a word as to the justice or the policy of the recent legislation, he considered that the question had become one of great importance, and might well be discussed, not with reference to the fencing of machines only, but with reference to all matters affecting accidents in works and factories. It had been his lot for some time past to be engaged in planning and equipping large works, and it had been clearly brought home to him how essential it was in the employer's interests—as a matter of pounds, shillings, and pence, apart from higher motives—to study the prevention of accidents. It was not

(Mr. Mark Robinson.)

only a question of fencing machines, shafts, or engines; everything about a shop might give rise to an accident. A slippery floor, caused by oil being spilt where it ought not to be spilt, might give rise to an accident; an overcrowded shop with castings piled on top of one another might give rise to an accident, for a man by stumbling might bring down the pile upon his foot and crush it. The upshot of any such inquiry should be an improvement in laying out of new shops, and a great smartening up in the methods and arrangements of many existing shops. A point which might easily escape attention, until an accident occurred, was the dangerous nature of many shop staircases and ladders. These were often much steeper than was desirable for men carrying burdens up and down. The factory inspector saw no sufficient ground perhaps to find fault, but if the staircase were less steep an accident was less likely to happen. A little while ago in the works he had referred to, he noticed a wooden foot-bridge over a railway, with rather long flights of steps, the latter having 11-inch treads and 7-inch risers, no doubt a good ordinary staircase for a suburban villa. But it was out of doors, exposed to frost, and his colleagues and he came to the conclusion that it would be better to spend a good deal more money in introducing landings in the long flights, and in making the steps 12 inches by 6 inches; the results of a single slip upon a frosty morning might cost the owners far more than the alteration of the bridge. It appeared to him that the whole thing should be looked at anew, and that employers and managers and foremen would all do well for their employees if they gave their minds very largely to this question of the prevention of accidents. Only people on the spot and in the shops could really say what the dangers were, and what could be done to lessen them.

Discussion on 4th April 1902.

The President reminded the members that Mr. Ireland at the last meeting had curtailed his remarks on account of the short time available. Mr. Ireland was not able to be present that evening, he was sorry to say, owing to his being in the doctor's hands, but he had forwarded some supplementary notes which the Secretary would read.

Mr. W. F. Ireland sent the following remarks, which were read by the Secretary. He said that in his remarks at the last meeting he dealt with the subject in a general way, and with a subject so varied and with so little time at their disposal, it was difficult to descend to detail.

In one's search for a perfect or standard guard, he did not think that the conditions enumerated by Mr. Johnson (pages 241–242) could be much improved upon. The only alteration he would suggest would be in the third condition. If possible the guard should be made, so as to permit oiling the machine with the former in place. This was generally possible in the case of wire guards; metal guards were sometimes provided with holes for that purpose. It was not always necessary to cover the hole, but if from the size this was desirable, a cover hinged like a keyhole cap might be provided.

The guard most often required was a protection for the "ingoing" side of spur wheels, or of belts and pulleys, that is to say, where the wheels or belts and pulleys were running into contact. These should almost invariably be guarded, the only exception being where the speed was *very* low, or the belts very light. In the case of heavier belts and those running at higher speeds, the belt itself should be guarded, as there was danger of abrasion or laceration from the belt or a projecting rivet head, and in the event of a belt breaking, it was desirable to prevent it flying about to the injury of the workpeople. For the latter purpose a strong and rigid belt-race was generally necessary.

(Mr. W. F. Ireland.)

In the fencing of spur wheels a complete cover was generally the only perfect guard. Edge guards, such as those illustrated in Fig. 7, Plate 23, of Mr. Johnson's Paper, were to be deprecated. These guarded the point of contact from the front only, and left the side quite exposed, which was a fruitful source of accidents. Partial covers, such as those illustrated in Fig. 1 (page 242) of Mr. Johnson's Paper and Fig. 8, Plate 12, of Mr. Platt's, were also faulty. They removed the danger from one point, but introduced it, although in a less degree, at another. In such cases there was danger of jamming between the wheel and the guard; he recently investigated such an accident in an engineering works. Where this style of fencing was most often met with was in the case of the bevels of drilling machines, the only guard provided being often a plate of sheet iron on the ingoing side. The types of guards illustrated in Mr. Platt's Paper (with perhaps the exception of Fig. 8, Plate 12), and in Figs. 3, 4, 6, 8, 10, 14, 16, and 18, Plates 22 to 24 of Mr. Johnson's, could not, he thought, be improved upon for their several purposes, and they contained sufficient to enable one to tackle most cases.

Mr. Platt (page 222) mentioned that extra precautions had to be taken with machines for Russia, owing to the more stringent regulations in force there and the class of people to be dealt with; in consequence some of the guards illustrated seemed to be more than was really necessary. But in the devising of guards, even in this country, the personal equation should be eliminated as far as possible, and they should depend as little as possible on the intelligence or the presence of mind of the workman. In some machines where fencing was difficult, instead of a guard, a belt striking gear, accessible from all the working parts of the machine, was provided, so that if a person became entangled in the machine he had the means at hand to stop or reverse it. He himself recently investigated an accident where an experienced man had one hand caught in such a machine while the other was resting on the belt-shifting lever, and yet he had not the presence of mind to pull it. If this were so in the case of a man, it was more likely with women, and it illustrated the importance of providing guards wherever practicable.

An automatic reversing gear had lately been invented for mangles —a source of serious accidents—which came into action when a hand or other foreign body came too near the point of contact of the rollers, and rendered roller accidents practically impossible. This was an illustration of what could be done by engineers when they took an interest in the subject, and emphasised what he said at the last meeting about their being the people best fitted to deal with the matter.

He was glad that Mr. Platt emphasised the advantage of pulleys without arms. In the case of armed pulleys the danger could be removed by filling in with sheet iron. Just the other day he came across a source of unnecessary danger in an engineering shop. A shearing machine beside a main passage was kept constantly running during the day, although used only at intervals. When not being used, there was the danger of a workman stumbling under the knives. Lathes provided another source of danger, owing to the small amount of clearance allowed between the fixed headstock and the bottom edge of the spur wheel at the head of the cone pulley, and he had known turners' hands get jammed there.

Mr. Oscar Harmer said that Mr. Johnson at the commencement of his Paper remarked that the Workmen's Compensation Act of 1899, together with the exacting requirements of factory inspectors, had compelled engineers to pay more attention to the subject of guarding machine tools. Doubtless the Workmen's Compensation Act and the Factory Inspectors had caused the users of machine tools to look into the question of guarding machine tools more closely; but in his opinion the people who should look into the guarding of machine tools were rather the makers than the users.

Regarding the materials Mr. Johnson mentioned from which guards could be made:—

(1) *Timber:* This in the speaker's opinion should not be used as a guard at all, excepting as a fencing round belts, such as planing machines, and round the cone pulleys of radial drills etc., where the cone pulley was attached to the base plate of the machine.

(Mr. Oscar Harmer.)

(2) *Cast Metal*, usually iron: In his opinion this was by far the best material to be used if the guards themselves were suitably designed.

(3) *Sheet Metal:* This in his opinion was an entirely unsuitable material for guarding machine tools, as it easily got dented, knocked out of shape, the joints frequently sprung open, and the raw edges of the sheets were liable to cut the men.

(4) *Hoops, Rods and Bars of Metal:* These in his opinion should only be used for fencing machinery, such as the change gears, etc., on the headstocks of big lathes.

(5) *Wire Work:* He did not think that wire work made good guards at all, although the author certainly showed one or two very good examples of machines guarded with this material.

He considered that the guarding of moving parts of machine tools should be considered in their design. He had brought a number of photographs illustrating the various points that he would mention. Machines should be so designed as to receive guards for some parts; other parts should be so designed that the part itself formed its own guard. To make this matter clear he would call attention to Proceedings 1901, Fig. 72, Plate 36. This showed a large hexagon-turret lathe, the headstock of which was designed to receive the gear guards, which were of cast-iron, and completely protected the whole of the gearing. On the front of the lathe, immediately below the headstock, would be noticed a gear box, from which was taken the leader shaft for operating the screw-cutting mechanism of the saddle and the feed shaft, for operating the sliding and surfacing motions of the saddle, and the sliding motion of the large turret slide; this gear box was designed so that it formed its own guard, and Fig. 35, Plate 25 (Proceedings 1901), showed the inside of it, in which there were two sets of three bevel gears and two sets of three change-feed gears. The whole of these gears were very effectually guarded by the design of the box. The saddle was fitted with an apron, which had sliding, surfacing, and screw-cutting motions, combined with automatic trips and interlocking mechanism. On Fig. 72, Plate 36 (mentioned above), it would be noticed that none of the gearing in this apron could be seen; the inside of the apron, Fig. 73, Plate 36 (Proceedings 1901), showed that the design of the apron itself formed a most complete guard. The apron on the turret slide of this machine also formed its own guard, Fig. 74, Plate 36 (Proceedings 1901).

Fig. 22, Plate 25, showed a large turret lathe for bar work. The gears on the headstock of this machine (of which there were three pairs) were completely guarded; there was also a guard to the chuck of this machine. The feed gearing at the headstock end of the machine was also completely guarded, and the gear box on the front of the bed under the headstock formed the guard for the gearing it contained. The whole of the mechanism in the apron of the turret slide was completely guarded by the apron itself, which was provided with chasing mechanism, right and left-hand power traverse, and a quick and slow feed-motion with interlocking mechanism and trips.

Fig. 75, Plate 37 (Proceedings 1901), showed another hexagon-turret lathe, which was completely guarded, namely, on the headstock, the gear box and change-feed gears, and the reduction gearing in the apron. The apron on this machine was a case again where the apron was designed to carry not only the gearing, but to form its own guard.

Fig. 21, Plate 25, showed a large vertical milling-machine, the back gears of which were above the belt-pulley on the spindle, and they were protected by a guard attached to the machine, which completely covered them. The whole of the feed works were carried in a box on the front of the machine, and this box was designed so as to carry the gears, and at the same time protect them. The feed motion to the circular table was also completely guarded; on this machine there was not a single gear in view, although on one provided with similar motions he recently counted no less than twenty-seven gears in clear sight.

The illustrations referred to above clearly showed the points he considered should be aimed at in designing machine tools. Some of the guards illustrated by the author were very good, and some were good, although they should not have been necessary.

Wire Guards on Radial Arm Drill, Fig. 7, Plate 23: The guards for the back gearing should have been incorporated in the design of the machine.

(Mr. Oscar Harmer.)

Guards for Carriage Gear, Fig. 7, Plate 23: The machine should have been designed to have protected effectually the parts shown.

Protection of Driving Belts, Figs. 10 and 11, Plate 23: He thought that this was a very good form of guard.

Figs. 14 and 15, Plate 24: These guards appeared to be unnecessary, as there was surely no danger from the small machine of which these guards formed part; especially was this the case regarding the jockey pulleys and spindle pulley.

Figs. 18 and 19: It seemed scarcely necessary to have provided the small feed-pulleys shown in these illustrations with guards, and in these last two cases it seemed as though the owners of these machines had suffered from a factory inspector.

He thought the designers of machine tools in this country very rarely covered sufficiently the moving parts of the machines they designed. Some few years ago his firm commenced putting on guards to a few of the machines they manufactured, but now they never thought of designing a machine tool and leaving any of its gearing exposed, and they would not be satisfied with guarding these moving parts by wire work, as a guard, to be effectual, should be as near as possible air-tight, so as to exclude dirt and dust, and in many instances chips, and other large articles which would break parts of the gearing.

Mr. Druitt Halpin found that the trouble with lifts chiefly arose through minor details, such as door-fastenings and approaches. It was very seldom, or relatively seldom, that accidents happened with the cage or the lifting gear, or the overhead gear, though curious accidents occasionally did happen in that way. It was very necessary to be careful in protecting the openings to the lifts, and too many precautions could not be taken. He believed that a good strong mechanical gear like Mr. Ellington's, which was positively and mechanically locked so that people could not open the doors, was a safeguard, and probably some of the electrical interlocking gears were fairly safe. But to make absolute safeguards under ordinary conditions, without going to great expense in details, was exceedingly difficult. It might be thought that with good strong double doors well rabbeted together, and having a throw-over catch on the inside, matters would be reasonably safe, but there had been an accident within a thousand yards of the Institution with a lift of that kind. A woman wished to use the lift, and as the doors were not open, and she could not get them open by knocking or ringing, she got a large carving knife and inserted it in some way in the rabbet of the door, forced the gate open, and without any intention of committing suicide fell down four storeys. It was almost impossible to deal with a case of that kind, and such cases were continually occurring. People found out all kinds of ways to get at the doors. Another thing that required very great precaution, to which some attention had been drawn in Mr. Walker's Paper, were hand-ropes. In numbers of cases ropes were exposed, and they were a great temptation in buildings much frequented by messenger boys and telegraph boys, who very often brought about accidents through playing with the ropes.

Mr. G. J. L. Blenkinsopp, H.M. Inspector of Factories, remarked that a previous speaker had said that one of the illustrations seemed to show that the machine had suffered from a factory inspector, as if a factory inspector was a person who would do them any harm. What would the fencing of machinery have been without the factory inspector? The factory inspectors would be only too glad if clever mechanical engineers would do all the fencing for all the machines which were sent out. The work of the factory inspector must not be judged by what was seen stuck on to an old machine which had been in the factory for many years. On such machines it was necessary to put the best thing possible, and he thought on the whole the inspectors were very successful. At the same time it would be far better if the engineers who made the machines could do the fencing, but they had never learnt to do it. His experience was that some of the worst machinery was to be found in those shops making machine tools and other things; at least in such shops there was a great neglect of fencing. He had noticed in one of the Papers that a cast-metal guard was suggested for emery wheels, but if an emery wheel running at a great pace burst, it would smash the

(Mr. G. J. L. Blenkinsopp.)

cast-metal guard all to pieces, and would be a source of far more danger. Factory inspectors were very glad to have any instruction they could get, and he was sure that mechanical engineers, men of knowledge and experience, were capable of giving them instruction, though he thought on the whole factory inspectors had worked well and had done a great deal of good. A remark in one of the Papers raised a question which he had had in his mind for a long period, namely, that the fencing should be so placed as to enable the attendant or the engine driver, or whoever it might be, to do his work from outside the fencing. That was a very wise idea, and he had striven for it all along. Miles of fencing might be put up, and no good be done. In an engine or other machine the fencing should be so placed as not to interefere with the work, and if that idea was spread abroad amongst machine makers, they would be able to do most of the fencing without anybody "suffering" unfortunately from the factory inspector.

Mr. H. F. L. Orcutt said he had made a few extracts from a report, which had been very exhaustively made by the Labour Bureau in America on the effect of the German laws, which were very stringent, and had been in force for many years. Statistics had been gathered in connection with the matter, which were rather instructive with regard to machinery which had not been guarded as thoroughly as it was on the Continent. Probably the Americans were about the worst offenders in the way of guarding machines with whom he was acquainted. They did not pay much attention to such things, and considered them of no account in many cases; they were now however obliged to consider them. The extracts were very short but rather instructive. The first ran as follows: "After many years of guarding machinery we put all the extra fencing guards, protection of all sorts, and find no corresponding decrease in accidents. This elaborate mechanism seems often to have the effect of making the men even less careful." A mill-owner, speaking of wood-working machinery in the Hartz Mountains, said: "When I got my saws and trucks so carefully guarded that it seemed to me nobody could get hurt if he tried, the number of accidents decreased scarcely at all. I am convinced that the men are more careless when the protection is too elaborate." Another extract ran as follows: "Taking all this into account, the extremely important fact must be dealt with that the testimony under this law shows that the mechanical element in this problem can be so easily exaggerated as to obscure the other factor, which is at least of as great an importance, the man himself." He thought those extracts were instructive. They would not apply to machine tools as much as to wood-working machinery perhaps. In machine tools he entirely agreed with Mr. Harmer that it seemed impossible to guard them too much, and he thought the machine-tool maker should do it for his own interest as much as anybody else's. With regard to wood-working machinery, in Germany he was intimately in contact with the work for several years, and found the men very careless indeed. For instance, what was called a buzz-planer was so thoroughly guarded that one could hardly get into the machine with a piece of work, and the men were discovered repeatedly removing the guards. That led to the point already spoken of, that engineers themselves should do the guarding, and they really ought to be ashamed that they were compelled to do it. With all due respect to any legislators or their representatives in the way of factory inspectors who might be present, they could not be all engineers and could not understand engineering problems; and they would legislate, and they would inspect! If engineers attended to the matters, it would not be necessary to legislate so much, and it would not be necessary to have the army of inspectors, under which many engineers were continually suffering, according to the talk going on. It was the same as with a good many other problems; the engineer was considering the mechanical problem, and had considered it for many years without properly considering the human element which came into the management, operation, and manipulation of all machines, and he was very sorry they were only just beginning to take up the question. He noticed that Mr. Johnson in his Paper said they were compelled to take it up, but if they had attended to it years ago and studied the problem, he thought it would have been very much better. Another case for illustrating it was found in the

(Mr. H. F. L. Orcutt.)

general factory inspection relating to sanitary arrangements and the comforts of the men. Manufacturers were gradually being compelled to do those things which they never ought to have had forced upon them.

Mr. H. C. D. Fearon, H.M. Inspector of Factories, wished to endorse thoroughly what had been said that it ought to be the place of the maker, and not of the user, to supply guards; and he thought it a great pity that there was no means of compelling all makers to do this work, as already done voluntarily by some of them. With regard to the circular-saw guards, he supported Mr. Johnson in insisting on the importance of riving knives. There were a great many guards now in use which had no riving knives, but he believed one could be fitted to every class of saw. Far more preventable accidents occurred at the back than on the top of circular saws, as, when there was no riving knife, the wood was caught in the teeth at the back, and came flying up over the saw, hitting the man on the head, or, if heavy, was thrown straight back, catching the man in the body and possibly killing him; and again, the man standing at the back of the saw taking the wood off the bench was always in danger of getting cut. He remembered when he first went to work in Bethnal Green amongst the wood-box factories, there were continual accidents to the small boys who took the wood from the back of the saws, in which they lost parts of their hands; that was before riving knives were fitted, but now that they had been fixed on practically all that class of saw, such accidents were almost unknown. With regard to gas-engines, it was a most important thing that, when an engine had to be started by hand, the fly-wheel guard should be made to come right away, only leaving the end of the shaft covered. A great many fly-wheels were guarded, so that only a piece of the guard opened and there was only a small bit of the wheel to start the engine by, which introduced the new danger of a man being caught by the wheel and jammed between it and the uprights supporting the guard. Such guards could be made like a window to lift up, like a venetian blind, or with doors to open or slide on one side.

As to hoists, one very frequent cause of accident not mentioned was due to things falling down the well on to the man in the cage, and a roof ought therefore to be fitted to it. He had been to two inquests on men who had mistaken the hoist doors for the ordinary door of the room; and owing to such accidents a great many firms had now adopted the excellent plan of painting the lift doors with the word "Danger" or "Hoist," so that there should be no mistake made with regard to it. The grip that held the cord to the cage, as described by Mr. Walker, was an important safeguard, as without it accidents were happening continually if the cage was either moved by somebody on another floor, or, especially in hydraulic hoists, crept away from the floor on which it was left; the man came back thinking the cage was there, stepped forward, and pitched down the hoist well. It was also important to fit sloping boards under all projections from the sides of the well and under each floor, in order to push back a head or foot projecting out of the cage, and prevent its being crushed between the floor of the rising cage and such a projection or a floor of the building.

Mr. Sidney Tebbutt noticed that in Fig. 6 (page 218) of Mr. Marshall's Paper the end of a shaft had been covered over with a cap of tin or some other kind of metal. It was constantly happening that those ends were left long for some future possible use in connection with pulleys; and a very easy method of guarding was to put a cap on and not to fasten that cap. If an ordinary tin fastening was fitted on easily, and oil was put inside it, it would be found that it would always revolve with the shaft, and if it was touched it would stop at once. That was a very simple method, and did away with the necessity of making any method for holding it, which was very often awkward to do and obstructive. He had in one of his places a similar device, which was suggested to him by a factory inspector, and it turned out very well indeed. He was specially interested in laundry machinery, and it was well known such machinery was a source of a large number of small accidents; they were seldom very serious ones, but every now and then there was one in which an arm was almost destroyed. A workwoman's hand often got between the

(Mr. Sidney Tebbutt.)

rollers. It appeared to him that there was no danger whatever in the case of a machine in which there was a roller revolving against a surface which was stationary, as was often the case in laundry machinery. He had never known of an accident; and he had experimented himself with his fingers, touching a moving surface with another surface above or below, or close to, which was not moving, and as far as he could see there was no danger at all. The surface which was stationary helped the hand to hold back as much as the moving surface tended to pull the hand in. But in the case of two rollers running together it was different. Something had been mentioned in the discussion about throwing the machinery on the reverse motion in case of an accident, but he thought the whole idea was a fallacy and mistake. When a person was caught, he did not think what he was doing, and was therefore unable to throw back the starting or the reversing lever or bar. As a matter of fact he ordered a machine some time ago, which had a reversing motion. It was on the three-pulley system, the central being stationary and the two side ones being fixed. He had one of the two fixed pulleys taken off, so that the machine could not be reversed at all, for the very simple reason that if there was a reversing motion the workpeople would probably use it at some time or another carelessly or excitedly, and get their hands caught and injured. They could not do so on the forward motion because of the guard. By having no reverse gear, when anything went wrong the workpeople had to turn the machine back by hand, when such was needed. It was absolutely necessary to safeguard the machinery in which there were rollers running together, so that workpeople could not put their fingers in or get their hands in at all. He had hardly ever seen any satisfactory guards at all, because they were obstructive on occasions, and not easily removable.

A good deal of laundry machinery in England was of American make, but his experience with regard to the guarding was not very good in that connection. When ordering a new American machine on one occasion, he pointed out that the gear wheels were not safely guarded, and desired them in the new one to be guarded. The next machine that came was guarded; but he had to inform the makers that he was sorry they had guarded the machine in that way, as he had had to take a hammer and smash the guard to pieces to get it off. The makers then asked what was the good of guarding a machine, when it was to be knocked to pieces with a hammer? It was absurd to put on guards which were so made and constructed that, when they needed at times to be taken off, the machine had to be pulled to pieces to do this. Guards ought to come away quite easily, and for that purpose the bolt-holes fastening cast-iron guards should be slotted, so that, instead of having to remove completely four or five awkward bolts, very often so arranged that they could hardly be got at, and of sizes for which it was difficult to find a spanner to fit, the guard would come away directly the bolts were loosened; and the whole thing could be done so quickly that it might be constantly used.

He had had a great deal of experience in connection with German inspectors, and had found them in the main very reasonable, as reasonable as the English inspectors were. But the German Government was a paternal Government, and was constantly forcing upon the inspectors the need of giving greater protection. The same thing would take place in England, if a paternal Government constantly forced the inspectors to take more precautions. Because an accident happened, there was not necessarily any reason for making arrangements to prevent that particular kind of accident happening again. There were many conditions so difficult that they could not be entirely guarded. He trusted he was not out of order in making his small protest against the extremely paternal method of government which England seemed to be getting under more and more. At present, if anything happened in this country which did not appear to be quite right, somebody said that somebody else ought to be forced to do something; but when they were forced themselves, they said they ought not to be interfered with, although quite willing somebody else ought to be. Fresh accidents which happened seemed to bring constantly some new regulation forward forcing something fresh to be done, and he was afraid it would not produce more common sense, or educate the workpeople, or effect their safety, or bring success or credit to the nation.

Mr. WILLIAM SCHÖNHEYDER referred to Mr. Marshall's Paper, where an arrangement was shown (page 216) for turning a fly-wheel of an engine round previous to starting it. It might be a very good arrangement, but he thought a still better arrangement would be, instead of having the pinion which was in the fly-wheel rack on a straight feather (so that it was necessary to pull the wheel in and out by hand), to have a very coarse thread cut on the spindle and the pinion tapped to suit in such a direction that when the engine was turned round by means of a handle, the pinion dragged itself into gear with the wheel, but the moment the engine started of its own accord and took charge, the pinion was automatically thrown out of gear. In that way there was a very small chance of a man being caught by the handle when the engine started running.

With regard to Mr. Walker's Paper, he wished to ask whether the arrangement he had seen in a good many lifts to prevent certain accidents was still in use, or, if not, why it was disused? On every floor there was a certain portion of the floor cut away, and a flap provided which could be lifted above but not below the level of the floor, and a similar flap was provided on the floor of the hoist itself. That appeared to prevent anybody having their head or toes nipped off. It acted when the lift was going up or going down, and seemed to be a very effective arrangement, and very simple. Another question he wished to ask Mr. Walker was whether hoists generally were in any way under inspection—whether hoists had to be passed by the Board of Trade in the same way that railway signals had to be passed, before a new railway line was opened? A couple of years ago there was a so-called accident to a hoist in a railway station in London, and some persons were injured, although no one was killed. In that case it was no accident, but simply faulty design, inasmuch as the weigh shaft carrying the counter balance-weight had a factor of safety of only a little over 3. Was it a fact that hoists of that description were allowed to be put up and used by the public? They were very unsafe. In that case the shaft being alternately bent from side to side, the fibres were in alternate compression and extension, so that the factor of 3 was perfectly absurd.

Mr. P. V. Vernon thought that the illustrations exhibited some very ingenious and effective guards, but he noticed that a great part of the gearing, apart from the appliances the photographs were intended to illustrate, was entirely uncovered. That, however, he only mentioned incidentally, and wished to confine his remarks entirely to the question of machine tools. He held very strongly the opinion that guards on machine tools, particularly gearing guards, should form an essential part of the design of the machine, and he based his opinion mainly upon three grounds: (1) guards embodied in the design were of neater appearance and were not so unsightly as guards which had to be added to a machine after the design was complete; (2) such guards were much more effective, as the design of the machine could be modified to suit any awkward conditions which might arise; and (3)—the most important of the whole three—guards which formed part of the design of a machine were supplied with the machines, and therefore caused no trouble or inconvenience to the purchaser of the machine after it had been delivered at his works. In addition to the function of a gear guard or any other guard as a protection to the workmen, there were certain other purposes which such guards should serve. Guards in his opinion should serve to keep dust and dirt out of the working parts of a machine. On looking through Mr. Johnson's Paper, he could not see how the wire guards suggested by him would serve that purpose. Mr. Johnson claimed that the guards could be made with hinges so that they could be swung out of the way for cleaning purposes, and to get at the mechanism. An effective guard would not need to be swung out of the way for cleaning purposes, because it would prevent dirt from getting in, and that, in the case of high speed gearing, which was required to run silently, was a most important matter. Mr. Johnson's guards possibly would prevent a certain part of the dirt and clinkers getting in, but would let small pieces in very easily. Another objection to hinged guards was that they were hinged to move away from their stationary position, when the operator was working upon the mechanism or changing the mechanism behind the guards; that was the very time when such a mechanism was

(Mr. P. V. Vernon.)

most dangerous, and when such guards were most ineffective. In most cases machines should be so designed that it was not necessary to remove the guards at all in order to adjust the mechanism. As an instance he might mention the change wheels of lathes. Arrangements for protecting change wheels had been shown in the Paper, but it was a modern tendency to make all changes where possible in the speeds and feeds of lathes by means of clutches, sliding feathers, or other appliances which could be worked from the outside, without entailing any risk of danger to the operator. Another function of guards was what he might call an incidental function; they served as oil-baths. A guard round a worm served as an oil-bath, and round a worm wheel would serve to keep the oil from flying about. That was also true in the case of all high-speed gearing in which there was a tendency for the oil to be thrown off by the centrifugal force. In his opinion a wire guard would not have much effect in preventing oil from flying. The main justification for such guards, as had been shown in the Paper, was their addition to existing machinery and satisfying the demands of factory inspectors in connection with old machinery which had been in place for some time. He felt convinced that the present tendency of machine designers was to so design machines that they were safe when sent out, and that nothing need be done in the way of protecting the machine by the purchaser of the machine when it was delivered.

The President observed that a remark made by Mr. Vernon (page 274) might rather appeal to Mr. Powrie, namely that all machinery should be capable of being operated without the removal of guards. One of the troubles connected with the efficient guarding of some classes of printing machinery was that certain guards must be removed for what was called "making ready," and he thought that was the most troublesome problem that printing machine makers had to tackle—the provision of suitable guards that could be removed easily for the purposes of adjustment, and replaced easily before the machine was started.

Mr. **WILLIAM POWRIE** said he had tried to put as much protection on the printing machines turned out by his firm as was necessary, and he certainly thought all moving parts, such as wheels, whether spur or bevel, ought to be protected so that the minders of the machines could not put their hands in and get them injured. But it was surprising how people working and attending to machines would accidentally put their fingers into places where they had no business to be. Guards should effectively protect the machine when at work, and must be removable to make alterations and adjustments in the machine. Protecting printing machinery was much the same as the protection of other machinery, especially that shown in Mr. Platt's Paper. He had admired the effective way in which the cotton machines were protected, and was inclined to think that printing-machine makers, especially in this country, would do well to follow those examples somewhat. He had noticed that machines from Germany or France were much better protected than English-built machines, and he was in favour of making the protection of machinery as complete as possible. He did not think that engineers should find fault with legislation for the purpose of protecting the public generally, because by emulating each other in protecting their machinery, the probability was that the best would win the approbation of purchasers in the end. It was a little difficult to know where to stop in putting additions on machines, but if designers of machines considered the protection more effectively when they were designing, they would find that users would give preference to those tools and machines which were not only efficient in the production of work, but efficient in the protection of the workers.

Mr. **R. A. BELL** had been interested to hear two gentlemen representing machine-tool makers suggest that the proper people to put guards on machine tools were the machine-tool makers. No doubt they were the right people, but he could not help feeling that the suggestion conveyed one for the man working the machine, and two for the machine. It appeared to him that their great idea of

(Mr. R. A. Bell.)

the guard was to protect the wheel from chips, etc., which was undoubtedly the right thing.

He was very pleased to hear one of the factory inspectors state that, in his opinion, plenty of room should be left around wheels, and that guards should be built so as to be easily removable. In a great many cases where men had to get at various parts of engines, etc., the guard was much more dangerous than the machine itself. The great thing to his mind in protecting machinery was, not to protect it from the man who had to work it, but, to quote an expression he had recently come across in connection with some electrical apparatus, to make it "fool proof."

One of the factory inspectors, speaking on the subject of lift protection, mentioned with approval the device of a bar which crossed the front of the cage, working a wedge to grip the hand-rope. On that day he had travelled in a lift fitted with that appliance. The bar folded down across the front of the cage, and should have rested in a small socket, and as long as the pin on which the bar hinged was a good fit, everything was all right; but as soon as there was a little wear, the attendant slammed the bar down, it missed the socket, and hung vertically down from the pin. People were able to get in and out of the cage without the bar being in any way moved, and as the hand-rope was in no way secured, accidents were just as likely to happen as if this particular appliance had never been fitted.

With reference to guards for circular saws for wood, he did not think that as a rule manufacturers' saw guards were as good as those which the users were able to make for themselves; as a rule they were too elaborate. A little while ago he was working in a place where there was a circular saw, and two different saw guards, both highly recommended by the manufacturers, were tried; they were however not found particularly effective, and the workmen found them extremely inconvenient, and eventually there was a rather nasty accident when one of them was in use.

One of the inspectors of factories suggested an extremely good design for a guard. The first saw guards which were purchased cost about £10 each, but the guard suggested by the inspector cost only about twenty-five shillings. A pillar was fixed at one corner of the saw bench, carrying at the top an arm swinging horizontally against a stop, at the end of the arm was a vertical circular hole, which was directly over the centre of the saw when the arm was against the stop. A vertical screwed spindle passed through this hole, and was prevented from turning therein by a key and keyway, the former on the arm. At the bottom of the vertical spindle was fixed a curve trough of inverted U shape, made from a short piece of slit copper pipe, and a nut on the spindle enabled the guard to be raised and lowered for different sized saws. This proved to be a much more effective guard, as being so much easier to adjust; the men liked it better, in fact, they worked with it constantly and would push the others out of the way.

With reference to Mr. Marshall's remarks on turning gear for engines, he thought accidents were most likely to occur with medium sized high-speed engines, which were so often put on a dead centre before the steam were turned on, so that the cylinders could be well warmed and then started up with a bar in the fly-wheel, and in this connection would point out the desirability of the holes in the wheel rim being made claw shaped, so that as soon as the engine took charge, the lever was immediately thrown out of gear. He considered that the idea of the papers and discussion was most happy, and likely to be of the greatest value.

Mr. David Carnegie said that his experience largely coincided with that of Mr. Harmer. While much was contributed to the safety of the machines and men by the introduction of guards, yet unless they were properly designed and made of suitable material, there was really a danger in their use. One of the dangers was that the guards were so fixed to the machines that, when the men wanted to oil the moving parts, they had difficulty in doing so, and if the guards were removed, they were not always put back, except when hinged; and the safety of the men was jeopardised. With reference to wire guarding, he thought it might be suitable under certain conditions, but not all.

(Mr. David Carnegie.)

He had made a tabular statement from the accidents occurring during the last twelve months in an ordinary shop running about 500 machines of medium size, and out of 102 slight accidents—although reported accidents—46 were due to chips entering men's eyes. He was a little surprised that no mention was made of guards for protecting the men from this danger. Often a guard would be seen introduced by the men themselves, such as a piece of leather slipped over the cutting tool to protect their eyes from the chips. Numerous goggles had been introduced, and many were on the market, but it was a difficulty to get men to wear them. Another cause of accident was from the "carrier," used on work running between the centres of a lathe, often catching the clothing of the workman while engaged on certain operations. To prevent this, a simple arrangement was to have a guard of sheet iron projecting over the carrier from the face plate. Another danger in the workshops arose from the use of iron floor-plates round machines. Accidents sometimes occurred by men, engaged at machines, slipping and falling against them; and that showed the necessity of all geared parts being properly guarded. He had found accidents arising from the jamming of the fingers between the dogs of the chuck and the tool rest; in some cases it was advantageous to have a guard over all the dogs, and attached to the chuck. Carelessness was one great source of accidents; the more machines were guarded, the more careless and indifferent some workmen became, and in altogether unexpected ways accidents would arise.

Mr. E. C. STEVENS thought the subject of Mr. Walker's Paper was an extremely important one to everybody connected with lifts—the owner, the user, and the maker. It affected all three in various ways. As a rule any accident occurring to a lift affected the owner's pocket, the user's person sometimes, and sometimes other people's as well, to a certain extent the maker's reputation, and it therefore behoved everyone concerned to eliminate those accidents as far as possible.

If greater care were exercised in working lifts, there would be far fewer accidents. It was better to have one man responsible for working the lift, and not allow anyone to have access to it. But that was not always possible, and in those cases where it was not possible, it was better to allow no one to bring the lift down from another floor at which he happened not to be (but where the lift was) by means of the hand-rope. In other words, if he wished to use the lift, he must enter from the floor at which it stood. By bringing the lift down, he might be taking it away from someone who used it, and who would return to it, and possibly, not noticing that the lift had gone, fall through the door down the well. A very good device, and one that provided for most contingencies, was the bar gripper mentioned by various speakers. It was a very useful device, and was fixed in the cage, and, when raised to allow access to the rope, gripped the rope; when down, the bar released the rope, and the cage could then be moved. This device had undoubtedly prevented many accidents. When used in connection with an automatic catch which latched the gates and prevented the gates being opened, except when the cage was at the corresponding floor level, most accidents were provided against. The electrical push button lift probably did provide for everything that could be foreseen.

He noticed that one old friend had come up again, the arrangement shown in Fig. 1, Plate 18. It was sometimes rather a pretty model, but he could not understand it being used in a lift itself, because it provided for a man falling down the well a certain distance. Probably he would never fall a greater distance than 10 feet, but it was surely better not to fall at all than to fall even such a short distance. Again, when the man had landed on the net of ropes, it was not a very comfortable place to be in; it was far better to provide catches of some kind on the door itself, and prevent him falling down at all. There were various devices, all more or less costly, which could be added, but the really important thing was to have the necessary devices, and not to lumber up the machine with cumbersome apparatus, which might run into a lot of money and really give no protection. In many cases they give a false sense of security. The proper way was to have a few simple devices, which made for the greatest amount of safety that was possible.

Mr. Harold H. Winston wished to say a few words in regard to the statement just mentioned of having one man governing each lift, or one man to be in such a position that he would know what floor the lift was on. Fig. 10, Plate 21, was a little device to prevent the man starting the lift where the well doors were open, and by which a man might know when the doors were shut or open. The arrangement consisted of a wire connected to the well-door, with a rising and falling weight, Fig. 11, carried in such a position as to be in full view of the lift attendant. When the doors were shut the weight fell, and was sufficient to drive a tappet out, which allowed the weight to fall in sight, where it became locked by the tappet. The door could not be opened until this catch had been pulled out.

Another arrangement to prevent a man getting out of the lift whilst in motion, and had gone sufficient distance for it to be dangerous for him to do so, was shown in Fig. 10. The arrangement consisted of a couple of runners, and on the cage itself a couple of short doors. Should the cage be started when anyone was in it, the doors were automatically shut, and that prevented a man jumping out when too late and striking his head against the top. The hinges were made strong enough to take the weight of the cage and usual load; so as long as they were open, it was impossible for the attendant to let the lift down whilst it was being loaded.

Mr. Harry Harmsworth, replying on behalf of Mr. Walker, who was not able to be present on account of being away from home, thanked the members for the consideration they had given to Mr. Walker's suggestions. He did not think there was very much that really needed replying to in any sense. Mr. Hoare (page 248) appeared to have misunderstood one point, which might perhaps be worth rectifying. He said that Mr. Walker suggested that doors should not be made self-closing. What Mr. Walker was really pointing out was that there was a certain amount of danger in having folding doors made self-closing, because if a lift was started before the doors were closed, there would be a tendency for the closing of the door to drive anyone who might be standing there down the lift shaft. He suggested, in the case of goods lifts in warehouses, having a sliding door such as was shown in Fig. 2, Plate 18, arranged to close automatically with the moving of the lift, and that was one of the simplest and safest protections which could be provided.

Mr. Schönheyder (page 272) had asked whether the hinged flap was used now to prevent anyone striking their feet against the landing as the lift passed. That was used in some cases, chiefly he believed in the case of the continuously moving lifts where the passenger alighted while the lift was in motion, and where such a protection was decidedly necessary. It was done occasionally in other cases, but not very frequently. Another question asked by the same speaker was as to the passing of lifts by the Board of Trade, before being used. He believed that that was not compulsory, and was not usually done, but in the case of some lifts which were used more for public purposes, such as the lift on the cliff at Folkestone, it had been frequently done, more he believed for the protection of the makers and users of the lift than as a matter of compulsion.

The main point of Mr. Walker's Paper had been generally accepted, namely, that accidents which arose in connection with lifts were generally due, not to the lift, but either to improper protection or to carelessness on the part of people using or working the lifts. The majority of the accidents probably happened through carelessness on the part of workmen, arising from that familiarity with danger which generally resulted in contempt. Other accidents had happened, as had been suggested, through carelessness on the part of the passengers, in sometimes endeavouring to get through the door, under the impression that it was the door of a room, when it happened to be the door of a lift. All those points could be chiefly guarded against by arranging that it should be impossible to open any door, except when the lift was standing opposite the floor, and by making it impossible for the lift to be started away from any floor, unless all the doors were properly shut and fastened. That arrangement seemed to him imperative for safety in case of lifts which were used for passengers. There were various suggestions made in the Paper for attaining that desired end. The only point

(Mr. Harry Harmsworth.)

as to which there might be some difference was as to how far the closing of the doors should be automatic, and how far it should depend on the lift attendant. Mr. Walker's view, which he ventured to support, was that the great aim was not to make the whole operation automatic, which might lead to carelessness, but to make it absolutely essential for the lift attendant to carry through the necessary operations for making protection absolutely successful; that might be best done by an arrangement which would prevent the lift from acting at all, unless all the protections were properly operated before the attendant began to move the lift. It had been suggested by one of the factory inspectors that the closing of the doors might start the lift. That was a thing which would be very undesirable. It should be impossible to start the lift, until the doors were properly closed and properly secured. He was sure Mr. Walker greatly regretted not having had the opportunity of being present, but he thanked the Institution on Mr. Walker's behalf for having had an opportunity of saying a word in reply to the discussion.

Mr. A. W. Storey, in responding for Mr. W. H. Johnson, who was unfortunately absent from England, said that he was pleased to notice the number of gentlemen who had spoken favourably of the various guards shown. There had been one reasonable objection made, as pointed out by Mr. Ireland (page 253), with regard to the projecting stud which holds the drill in position in the spindle, Fig. 3, Plate 22. This, he considered, might be looked upon as an oversight. Any projection on a revolving shaft, or even a plain shaft revolving, must be acknowledged as a great source of danger.

The point raised by Mr. Harmer (page 262), who seemed to advocate the use of cast-iron instead of wire work, was no doubt right to a certain extent. If all tool makers would take the trouble of having all their machines designed to receive cast guards, and would go to the expense of making patterns to protect the dangerous parts, if carefully arranged nothing as regards neatness and effective guarding could be desired; but this was only economical where machines were duplicated by the dozen, as the price of patterns would be covered by the quantity required. For one or two machines this would be very expensive, and even then there were various shop conditions, such as revolving belts, shafts, etc., for which machine-tool makers could not be expected to cater. He thought that Mr. Harmer had overstepped the mark, when he said that wire work was not a suitable material for guards. Only a very few firms supplied their machines fully guarded, and they had only given this matter their attention for the past year or so; he did not think their number would increase very much, unless compelled by law.

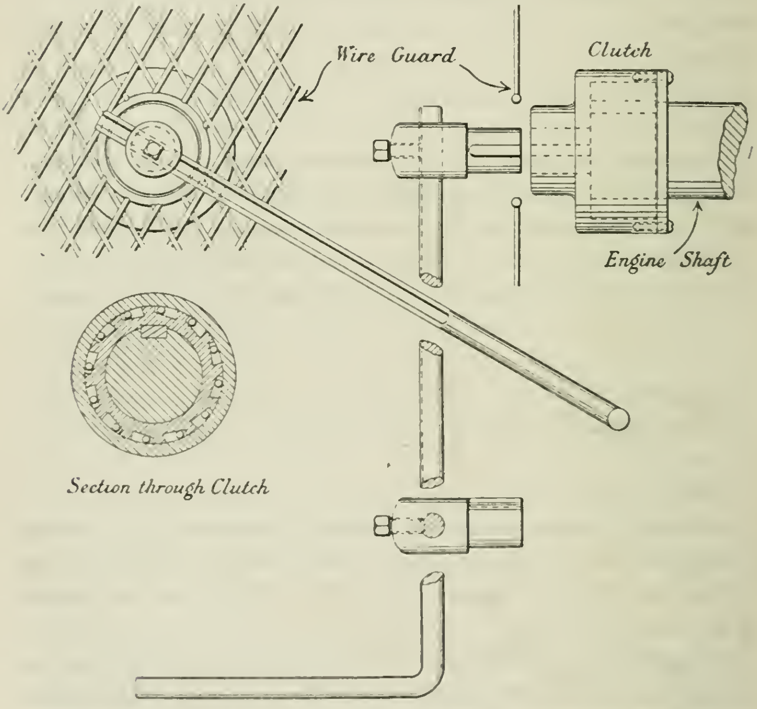
What then was to be done to guard the great number of machines that had been, and were being, sent out without guards of any description? It certainly was not to be expected that managers were going to incur the enormous expense of making awkward shaped patterns to obtain perhaps only one cast guard, when they could obtain a wire-work guard at less than half the cost of the pattern, which was in many cases equally effective and more suitable. For this reason only, wire work would continue to hold a high position among the materials used for guards. Then again, cast guards of large dimensions were much too heavy, while in other cases it was almost necessary to see through the protections.

Another point, raised in the discussion, was as to whether a guard should be screwed to the machine, or made to open. He was strongly in favour of those made to move out of the way, similar to that shown on Figs. 18 and 19, Plate 24. Experience had taught that if a guard had to be unscrewed to oil, or effect a change, it would invariably become detached from the machine altogether. It had been suggested that guards should be fixed, with openings left in them, to attend to the necessary requirements. He did not concur with this idea, because in a great many cases the opening offered very dangerous traps in themselves. It had been mentioned also that guards which opened were not a protection at the critical moment, but machines must be considered stopped at the time of changing, and ought not to be looked upon as a main shaft, which was continually revolving.

(Mr. A. W. Storey.)

He wished to draw attention to a subject which could not be taken under the heading of machine-tool guards, but which he thought might add to the value of Mr. Marshall's Paper on engine guards. A factory inspector had ordered that a gas-engine of 6 H.P. must not be started in the usual manner by the fly-wheel. The result of which was the fixing of a device, Fig. 7, whereby the attendant could revolve the engine by means of a handle until the necessary explosion occurred; the extra speed obtained thereby in no way effected the speed of the handle held by the attendant, and it could be detached from the engine, without the slightest danger, while the engine was running at full speed. The arrangement answered admirably, and was suitable for gas or oil-engines up to about 6 H.P.

Fig. 7.—*Safety Starting-Handle and Guard for Gas-Engine.*



The PRESIDENT very much hoped that the bringing together of the representatives of the Factory Department of the Home Office and the members of the Institution of Mechanical Engineers might result in some good, and in many cases remove friction which otherwise would have occurred.

Mr. C. C. W. HOARE, on behalf of the Factory Department, thanked the Institution for allowing the subject to be brought forward for discussion. Factory Inspectors, he admitted, were not perfect, and would obtain considerable information from the Proceedings.

The PRESIDENT said the Institution was quite as much indebted to the representatives of the Home Office for being present as the Factory Inspectors could possibly be for the invitation to them. The communications of the Inspectors had been of very great value in connection with the subject under discussion.

Communications.

Mr. J. H. CRABTREE, H.M. Inspector of Factories, sent some photographs of guards for machinery, which were illustrated in Plates 9, 16, 17, and 26. The following is a description of the various guards :—

Fig. 8, *Plate* 9, *Guards to Press-Cogs, and to Gas-Engine.*—The large press-cog has its teeth covered to the height of six feet. The pinion is covered entirely. The gas-engine is surrounded by a close-meshed wire guard.

Fig. 9, *Fence to Gas-Engine.*—Rails are placed all round the engine. To these rails is attached an iron plate so as to cover the face of the fly-wheel.

Fig. 10, *Fence to large Steam-Engine.*—A double-rail fence begins at the cylinder, and is carried on in front of the cross-head,

(Mr. J. H. Crabtree.)

connecting-rod, crank, eccentrics, fly-wheel face and rope-race. In too many cases this fence stops at the outward run of the cross-head.

Fig. 28, *Plate* 16, *Guard to Drawband-pulley.*—This drawband has a reversible motion, gathering in both above and below the pulley, according as the mule-carriage moves inwardly or outwardly. The points where the bands joins the pulley are fenced as shown. The pulley itself is a "plate" wheel.

Fig. 29, *Guard to Carriage Wheel.*—Here the slip is placed on the floor level. The guard is placed in front of the wheel, and a brush sweeps away any little obstruction, the guard itself preventing admission of fingers or toes of the spinners. The guard is attached to the wheel-bearing.

Fig. 30, *Guards on Headstocks.*—These guards cover cog-wheels where spinners are accustomed to do cleaning operations. These wheels have rapid motions and, if not covered, sometimes draw in cleaning waste and, with it, the operatives' fingers.

Fig. 31, *Plate Guard behind Headstocks.*—This iron-plate guard is attached to the back of the headstocks of the mule, so as to prevent "little piecers" and spinners from falling on the rapidly revolving pulleys there.

Fig. 32, *Back of Headstocks.*—This photograph shows the various rimband pulleys and scroll wheels which operate the movements of the mule-carriage. The rimband pulleys make about 750 revolutions per minute when at their greatest speed.

Fig. 33, *Guard for Carding Engine* (*Fairclough*). — When carding-engines have their cylinder-covers left open, the risk of accident to persons clearing the cotton strippings which hang in front of the cylinder is somewhat serious. The loss of an arm has frequently occurred from this cause. To prevent this kind of accident, a spring has here been attached to the cover, so that it cannot be left open after stripping or grinding operations. If required to be opened for a moment for observation, the treadle at the side of the machine will pull down the chain and temporarily raise the cylinder-cover.

Fig. 34, *Plate* 17, *Shuttle Guard on Jacquard Loom.*—This guard stretches the full length of the cloth without any intermediate fastening; it is attached to both ends of the slay-cap.

Fig. 35, *Shuttle Guard.*—This guard may be attached to the slay-cap, as seen in the photograph. It may be raised a little for the drawing of ends through the reed, and then it falls when the loom begins to weave the cloth.

Fig. 36, *Guards to Speed-frame bevels.*—Every bobbin is operated by a pair of bevel wheels, and every spindle is operated by another pair of bevel wheels. The bobbin bevels are immediately below the bobbins; the spindle bevels are near the floor. Both sets of bevels are covered on the top, front, and under sides by these guards.

Fig. 37, *Guard to Ring Frame.*—The guard to which a knob is attached covers several cog-wheels which gather in on the front side, and might crush the fingers of the operatives if unfenced. The other cogs seen in photograph move outwards in front.

Fig. 38, *Guard for draft wheels of Speed Frame.*—This guard bears a knob, so that it is easily removed in case of necessity for repairing. It rests on the front and back roller-shafts.

Fig. 23, *Plate* 26, *Guard to Emery Wheels.*—This guard is made to cover entirely the back and top of the wheels and as much of the front as possible. It is made throughout of wrought-iron rods and plates. The driving strap is seen at A. At D is the rest on which the grindings are placed. At E and F are seen the attachments of the guard. It will be seen that the wheel C has a large face-plate, great speed being a necessity.

Fig. 24, *Guard to Circular Saw.*—This saw when working travels backward and forward. When it is on its backward motion the timber is passed along the front of the guide C. The saw then takes its forward motion and cross-cuts the timber. The hood AB covers the saw in its "travelling" motions.

Fig. 25, *Guard to Circular Saw.*—This guard covers all parts of the teeth which are not in use. It has wings at AA which can be raised and lowered to any required level. The whole guard can be raised by the hand-screw at B.

Fig. 26, *Guard to Guillotine.*—A board is fixed edgewise between the two sides of the machine. This board has in it a number of observation holes through which the operations of the knife can be seen. The board is placed as low as possible so as to admit the tin-plate and debar fingers.

(Mr. J. H. Crabtree.)

Fig. 27, *Guard to tin-plate Bending Machine.*—In the process of bending tin-plate this hollow guard prevents the weight coming in contact with an operator's head or arms.

Fig. 28, *Guard to Power-Press for tin-plate workers.*—The tin-plate is drawn from side to side under the guard B, so that fingers cannot be admitted to the space where the tool falls. The guard is fastened to the side of the press as seen at A.

Mr. Ernest Parkinson wrote that Mr. Carnegie (page 278) had spoken of the dangers arising from unprotected lathe carriers, and investigation would show that in almost every workshop quite a large proportion of the accidents to lathe workers arose from this cause. It was true that many of these might be of a minor character, and might never be reported, being regarded by the turner with philosophic calm as his own peculiar heritage, descending to him from countless generations of turners, who had lived and worked among, and often dodged, and sometimes been trapped and maimed by the flail-like projections of revolving lathe-carriers. No other class of artizan was subjected to this particular form of danger, and this fact might account for the turner taking it so calmly as a part and parcel of his daily work, and a risk for which there was no remedy. Even the most skilful workmen were liable to accident from this cause, and familiarity with the danger begot contempt of safeguards. Some day, however, the penalty was exacted; it might be only a bruise, but was often a crushed finger, a damaged hand, or a ripped arm. Quite recently a case came to the writer's knowledge of a boy who only escaped serious injury through the thinness of his coat and shirt which tore easily, and thus released his arm; and not long ago, another case of a man who lost his arm because, under similar circumstances, his coat being better cloth, would not give way. In both these cases, the workman's coat sleeve was caught by the lathe-carrier.

The difficulty of devising an effective and easily-fitted guard, that should not interfere with the operations of the workman, or lathe, probably accounted for the almost universal use of unprotected carriers. In considering the provision of a guard, the following conditions might be laid down:—

(1) It must afford complete protection to small but rapidly-revolving carriers.

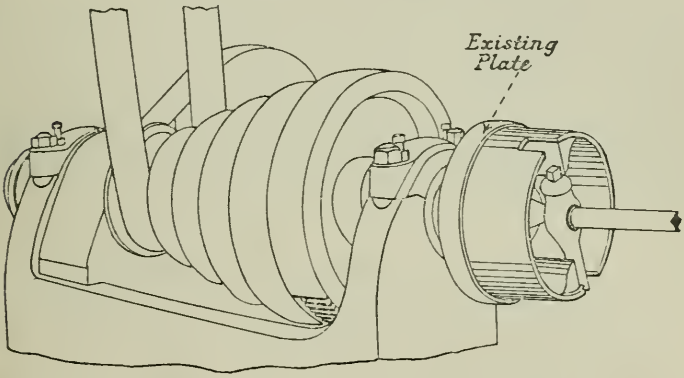
(2) It must admit larger carriers required for larger work.

(3) It must be of moderate dimensions, so as not to interfere with the other parts of the lathe, and to allow the tool to come "close up" to the carrier.

(4) It must be easily adaptable to existing lathes.

These requirements were fully met by the "Safe" Driver-Plate Attachment, Fig. 29, which the writer's firm were making. It afforded complete protection for short carriers, and would admit carriers with long projections, that might be required for larger work. Usually, small carriers revolved rapidly, and were manifestly more dangerous than larger carriers, which revolved more slowly. It was advisable, however, in cases where all the lathes were fitted with this attachment, to make the projecting tails of the larger carriers much shorter than usual. The outside diameter and width of these driver-plates were such as rendered work at close quarters with the carrier possible. Its design secured practical balance and the advantages of the "Clements" Driver. If preferred, however, the floating plate might be clamped firmly. It was fixed by screws to existing driver-plates, and the delay and expense of fitting to the spindle nose was obviated.

Fig. 29.—*Guard for Lathe-Driving Dog.*



Mr. W. F. E. Seymour, H.M. Inspector of Factories, wrote that Mr. Hoare (page 248) had spoken at some length on the question of lift guarding, so that he would only call attention to one point—the necessity of seeing that safety appliances, which should prevent accidents, were kept in working order. At a recent inquest on a man killed at the bottom of a lift shaft, by the lift falling from a height of sixty feet on him, it was found that the safety jaws, supposed to prevent such an accident, had been in the first place badly fitted, and secondly were filled with a hardened grease which rendered them useless.

Mr. Johnson's Paper, so far as it went, covered the question of machine guarding fairly fully, but the author did not seem to realise that "the exacting requirements of factory inspectors" were the outcome of the numerous accidents which every year happened in factories. The reports of H.M. Chief Inspector of Factories for the years 1895 to 1900 inclusive showed that the fatal and non-fatal accidents from machinery alone were as follows:—

Year.	Fatal.	Non-fatal.
1895	177	9,183
1896	280	12,658
1897	267	13,921
1898	289	16,487
1899	301	19,321
1900	372	23,035

It is probable that many of these might have been avoided, had a little more care on the part of the employer been exercised in seeing that his machinery was either well protected or in a suitable state for work.

Wood-working machines were responsible for many accidents, and it was necessary to have not only circular saws, but planing or surfacing machines and spindle cutters of various types securely guarded as to their cutting edges; good guards for these existed, and were used in many joinery works. Laundry machinery too brought about many accidents, principally to women, and the injury was often aggravated by the severe burns which often took place in steam-heated calender machines, collar machines and others. There was an opening for some one with an inventive mind to design practical guards for many of these machines, the nature of the work requiring special methods of protection.

Mr. Platt spoke of guards for machines being designed for machinery to be sent abroad, and the question naturally arose, "Why not for machines for home use?" It was surely easier to provide and fit guards to known dangerous parts of machinery while the machine was under construction, than to await a factory inspector's visit, and delay work while guards were being afterwards fitted. The design and planning of guards should take place in the drawing office, for then lugs and similar methods for attachment could be made on the castings, saving a large amount of what was, at the best, but patchwork afterwards.

Mr. Marshall's Paper, in Fig. 3 (page 214), showed an excellent method of guarding the moving parts of steam- or gas-engines. The wire-netting screen should never be omitted; a single or even double rail was not at all suitable or sufficient, as a recent fatal accident proved, where a man slipped forward and, falling under the rail provided, was caught and killed by the engine flywheel. Another important point was that the inside of a flywheel was as dangerous as the outside; a good guard here was a wing plate returned from the crank guard, completely covering in the spokes and edge of rim.

One of H.M. Inspector of Factories wrote that a common defect in the guarding of steam-engines was the neglect to fence the cross-head. A rail fence was not a sufficient protection in a high-speed engine; especially in the case of a large engine, with hood or trunk attached to or forming part of the cylinder, was there considerable liability to crushing or shearing. That point was not mentioned in

Mr. Marshall's Paper, where the part was shown exposed, as in Fig. 3 (page 214).

With reference to the guarding of textile machinery, he would like to draw attention to an official publication,* which had been recently issued, containing numerous plates and drawings.

Mr. S. R. PLATT, Member of Council, wrote that, as might be gathered from the discussion, opinions differed on the question of guards; but for the ordinary run of textile machinery, it might be maintained that, as a rule, an increase of guards was not likely to add to the efficiency of a machine from a producing point of view, though it might be otherwise in special cases.

In reference to the partial guard of the licker-in bevel wheel and pinion on the side shaft of carding engines, Fig. 8, Plate 12, which was spoken of as "faulty," (page 260), he might remark that by the trade generally it was considered satisfactory, and he might add that in the Blue Book "Report of two of H.M. Inspectors on the Prevention of Accidents from Cotton Machinery 1899," this guard was illustrated on page 80, and mentioned as "approved." His firm had however an alternative guard, illustrated in Fig. 7, Plate 12, namely a "complete guard to licker-in, bevel-wheel, and pinion," which could be supplied to order; some preferred that shown on Fig. 8, and others Fig. 7.

As to guarding all machines alike, whether for home or abroad (page 291), he could only say that his firm were always prepared to do this when requested, but as a rule machines were fitted with those guards which ordinary experience had shown to be generally advantageous; and it would only add to the initial cost, to apply extra guards where they were considered unnecessary, or were not wanted. It was therefore always a question of special order and extra cost, when arranging for a mill where more than the usual guards were required, and this must necessarily be the case in the large variety of the more or less intricate machines used in the textile trades.

---

* A Report on the Prevention of Accidents from Cotton Machinery, c. 9456; published by Eyre and Spottiswoode.

Mr. Henry C. Walker wrote, in reply to the discussion, that he regretted exceedingly his absence abroad at the time his Paper was discussed. He was fully in accord with Mr. Harmsworth (page 280) in the reply he had made to the discussion. Though in some cases a bar was used as protection to a hoist enclosure, in nine cases out of ten it could only be considered as a warning, rather than an absolute protection against accident.

Mr. Hoare mentioned the locking gear. In his Paper he referred to one that locked the starting gear and held it until the door on the floor opening was shut and locked; it was not as Mr. Hoare understood it, namely that the action of the hoistman locking the door started the hoist. In that case Mr. Hoare was quite right, as the man getting into the hoist might unfortunately slip. When he spoke of there being a few hoist accidents, he meant accidents from failure of hoisting machinery, as they nearly always arose from insufficient or ineffectual protection at the openings. Mr. Hoare made a valuable suggestion as to the door sinking instead of rising, which the author had at various times carried out; but, as he said, it was a little more difficult, and in some positions would be impracticable.

While not approving of a bar at the opening, he agreed with Mr. Stevens (page 279) as to the bar in the cage being a good thing; but not fitted in the way Mr. R. A. Bell described (page 276). He had seen one which evidently did not fulfil the conditions for which it was put up. He also considered the point Mr. Seymour raised (page 290) a very important one, namely, the necessity of seeing that the safety appliances, which should prevent accidents, were kept in working order. Lift makers periodically inspected and reported on lifts, and a large number of lift owners availed themselves of this safeguard; if more were to do so, many accidents would be avoided, for which the hoist should never be blamed.

He would like to add however, that having read the report of the discussion with such pleasure, he thanked those who had spoken, and was glad to see amongst the number those so qualified to do so, as Mr. C. C. Hoare, Mr. W. F. Ireland, and Mr. G. J. L. Blenkinsopp.

The Institution of Mechanical Engineers.

PROCEEDINGS.

April 1902.

An Ordinary General Meeting was held at the Institution on Friday, 18th April 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The Minutes of the previous Meetings were read and confirmed.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following eighty-five candidates were found to be duly elected.

MEMBERS.

Arnot, Arthur James,	Sydney.
Asbury, George Elias,	Newark.
Bell, Arthur Morton,	London.
Browne, Sir Benjamin Chapman, D.C.L.,	Newcastle-on-Tyne.
Clift, Clyde Ernest,	London.
Cloud, John Wills,	London.
Cook, Reuben James,	London.
Fitzmaurice, Maurice,	London.
Kitching, Henry Walton, R.N.,	Portsmouth.
Lazenby, Arthur,	Rugby.
MacNay, Arthur,	De Aar, Cape Colony.
Mathot, Rodolphe,	Brussels.
Monks, Frederick William,	Warrington.

Musgrave, Frank Everard,	Bolton.
Newman, William Edwin,	Melton Constable.
Noakes, Thomas Elias,	London.
Oldbury, Arthur,	Wednesbury.
Robins, Alban George,	Chester.
Rogerson, Thomas Bond,	Glasgow.
Ruthven-Murray, Ethelbert Thomas,	London.
Rutter, Henry Fillmer,	London.
Sayers, Ricardo John Henry,	Manchester.
Shawfield, Charles Edwin Campbell,	Wolverhampton.
Stodola, Aurel,	Zürich.
Wainford, Richard Hanbury,	Newcastle-on-Tyne.
Watkinson, Frederick George,	London.
Watts, Philip, F.R.S.,	London.
Westgarth, Tom,	Middlesbrough.
Wyles, David Dewar,	London.
Wyllie, James,	Liverpool.

ASSOCIATE MEMBERS.

Atkins, Evan Arthur,	Liverpool.
Bartram, Harry Alfred,	London.
Bevan, Ivor,	Liverpool.
Brewer, Robert Wellesley Antony,	London.
Burford, Henry George,	London.
Button, John William,	London.
Dack, William Herbert,	London.
Dawbarn, Reginald Proctor,	London.
Donaldson, James,	London.
Ermen, George,	Manchester.
Forgan, Charles,	London.
Garnett, Herbert,	Warrington.
Gledhill, Arthur Henry,	Halifax.
Hemingway, Ransome Leigh,	Wolverhampton.
Hoyte, Percy Siddons,	Plymouth.
Izod, Edwin Gilbert,	Rugby.
Jones, Thomas Morris,	London.

Kentish, Hubert,	London.
Kilroy, Willie Dickson,	London.
Kitsell, Archibald Edward,	London.
Linscott, Arthur Burrow,	London.
Matsubara, Takashi,	Chikugo, Japan.
McDougall, Hugh,	Runcorn.
Mitchell, James,.	Aberdeen.
Muggeridge, Harold Chisman,	Tinnevelly, India.
O'Connell, John George,	London.
Papworth, John Wyatt,	London.
Pittar, Albert Vyvyan,	London.
Poole, Richard,	Kingston-on-Thames.
Pulvertaft, Robert George,	Cork.
Stevenson, John,	Birmingham.
Taylor, Frank Coston,	Manchester.
Taylor, William,	Liverpool.
Tubbs, William Edward,	Isle of Man.
Urie, James Barclay,	Manchester.
Weston, William Newton,	London.
Wolff, Charles,	London.

GRADUATES.

Baker, Henry,	Manchester.
Barton, Geoffrey Berkley,	Glasgow.
Carrick, Joseph Ernest Cecil,	Gateshead.
Clifford, Arthur Campbell,	London.
Foster, Robert John,	Sheffield.
Frankau, George Neuberg,	Rugby.
Hamilton, Gavin James,	London.
Hancock, Percy Bolden,	London.
Hutchinson, Wilfred Leavold,	London.
Jepson, George Frederic,	Manchester.
Paul, Sydney Frank,	London.
Pimm, Arthur Watson,	London.
Powell, Henry,	Gainsborough.
Stevenson, Edward James,	London.

Swan, Herbert Anderson, . . .	Wallsend.
Tulip, Wilfred, ...	Newcastle-on-Tyne.
Webster, Arthur Guy, ...	Leeds.
Westacott, Percy, ...	Plymouth.

Transferences.

The President announced that the following three Transferences of Associate Members to the class of Members had been made by the Council since the last announcement:—

Chatwood, Arthur Brunel, . . .	Bolton.
Shawcross, George Nuttall, . . .	Horwich.
Threlfall, George, ...	Birmingham.

The following Paper was read and partly discussed:—

"Standardization of Pipe Flanges and Flanged Fittings"; by Mr. Robert E. Atkinson, *Associate Member*, of Leicester.

The President announced that, as the Discussion could not be concluded in one evening, the Council had appointed a Committee consisting of the Author and four of their number to receive further contributions during the next few months, and to bring the matter forward again in the Autumn.

The Meeting terminated at Ten o'clock. The attendance was 109 Members and 51 Visitors.

ANNIVERSARY DINNER.

The Anniversary Dinner of the Institution was held at the Hotel Cecil, Strand, London, on Thursday evening, 17th April 1902. The President occupied the chair; and the following Guests accepted the invitations sent to them, although those to whom an asterisk * is prefixed were unavoidably prevented at the last from being present.

*The Right Hon. the Earl of Selborne, P.C., First Lord of the Admiralty; His Excellency the Japanese Minister, Viscount Hayashi; The Right Hon. Lord George Hamilton, M.P., Secretary of State for India; Lieut.-General J. F. Owen, R.A., President of the Ordnance Committee; Rear-Admiral John Durnford, C.B., D.S.O., Naval Lord; *Rear-Admiral Wilmot H. Fawkes; *Sir Andrew Noble, K.C.B., F.R.S.; Sir A. John Durston, K.C.B., Engineer-in-Chief, Admiralty; *Colonel E. Bainbridge, C.B., Chief Superintendent, Ordnance Factories; Commander R. Clover, Naval Attaché, United States Embassy; Professor A. W. Rücker, D.Sc., F.R.S., Principal, The University of London; Mr. W. H. M. Christie, C.B., F.R.S., Astronomer Royal; Mr. R. T. Glazebrook, F.R.S., Director of the National Physical Laboratory; Colonel F. W. Tannett-Walker, Master of the Glass-Sellers' Company.

Sir Walter Peace, K.C.M.G., Agent-General for Natal; *The Hon. Sir Horace Tozer, K.C.M.G., Agent-General for Queensland; *The Hon. W. Pember Reeves, Agent-General for New Zealand; The Hon. Alfred Dobson, Agent-General for Tasmania; Mr. H. Allerdale Grainger, Agent-General for South Australia; *The Hon. H. Bruce Lefroy, Agent-General for Western Australia; *Mr. Thomas E. Fuller, Agent-General for Cape Colony; *Mr. John Howard, Agent-General for Nova Scotia; *The Hon. C. A. Duff Miller, Agent-General for New Brunswick; Mr. J. H. Turner, Agent-General for British Columbia.

Mr. Charles Hawksley, President of the Institution of Civil Engineers; Mr. Alfred B. Kempe, F.R.S., Treasurer of the Royal Society; *Sir William H. Preece, K.C.B., F.R.S., Chairman of the

Council of the Society of Arts; *Mr. J. G. Weeks, President of the North of England Institute of Mining and Mechanical Engineers; Sir John F. L. Rolleston, M.P., President of the Surveyors' Institution; *Mr. W. E. Langdon, President of the Institution of Electrical Engineers; *Mr. Henry Withy, President of the North-East Coast Institution of Engineers and Shipbuilders; *Dr. J. H. T. Tudsbery, Secretary of the Institution of Civil Engineers.

*The Hon. Sir Charles J. Darling, Judge of the King's Bench Division: *Mr. William R. Bousfield, K.C., M.P.; *Mr. H. W. Worsley-Taylor, K.C., M.P.; Mr. J. H. Balfour-Browne, K.C.; *Mr. Thomas Terrell, K.C.

Mr. Robert E. Atkinson; *Mr. Alfred Bache; *Professor F. W. Burstall; Mr. Dugald Clerk; Professor W. E. Dalby; *Mr. William Gowland; Mr. R. A. McLean, Auditor; *Mr. H. L. Millar, Treasurer; Mr. H. F. L. Orcutt.

The President was supported by the following Officers of the Institution:—*Past-Presidents,* Sir Frederick Bramwell, Bart., D.C.L., LL.D., F.R.S.; Sir Edward H. Carbutt, Bart.,; *Mr. Samuel W. Johnson; and *Mr. E. Windsor Richards. *Vice-Presidents,* Mr. John A. F. Aspinall; and Mr. A. Tannett-Walker. *Members of Council,* *Mr. Henry Chapman; Mr. Henry Davey; Mr. William Dean; Mr. Henry A. Ivatt; Mr. Henry Lea; Sir William T. Lewis, Bart.; Mr. James Mansergh, F.R.S.; Mr. Henry D. Marshall; The Right Hon. William J. Pirrie, LL.D.; Mr. John F. Robinson; and Mr. Mark H. Robinson.

After the President had proposed the loyal toasts, SIR WALTER PEACE, K.C.M.G., Agent-General for Natal, proposed that of "The Imperial Forces," which was acknowledged by REAR-ADMIRAL J. DURNFORD, C.B., D.S.O., Naval Lord, and LIEUT.-GENERAL J. F. OWEN, R.A., President of the Ordnance Committee.

In proposing "Our Guests," the PRESIDENT regretted the absence of the Earl of Selborne, owing to a family bereavement. He said they were honoured with the presence of the Japanese Minister, Viscount Hayashi, Lord George Hamilton, and the Agents-General of several Colonies. With regard to the latter, he would say that never were guests more welcome, for never had there been a closer bond between the Colonies and the Mother Country, or a greater reason and occasion for that bond. He was also glad to welcome the representatives of many kindred Institutions.

Lord George Hamilton, Secretary of State for India, in responding, said it was the province of the engineer to promote the Imperial feeling, and if they as engineers helped to bring together the separate portions of the British Empire, it was only fair that the Empire should contribute to the advantage of engineering. For the moment he would take one special branch of engineering that was capable, in India at least, of unlimited development, namely the railway interest. His great desire was that all orders for material in connection with the Indian railways should be placed within the limits of the British Empire. The reason why some orders for locomotives during the last two or three years had gone abroad was not on account of quality or price, but was mainly a matter of time, which in these days had become of more importance than price. It would be of some advantage, if they could adopt some measure of standardization, as had been done in the United States, and to that end he had called a conference in Calcutta. He had a profound belief that the British engineer could hold his own with all rivals under adequate conditions; and if the State and the profession combined their best efforts, they would hold their own. Mr. J. H. Balfour-Browne, K.C., also responded.

The toast of "The Institution of Mechanical Engineers" was proposed by His Excellency the Japanese Minister, Viscount Hayashi, who remarked that Japan fully recognized that much of the progress she had made was due to the advice and counsel received from members of the engineering profession. The toast was acknowledged by the President, who said that the Institution had done good work in the past, and showed no signs of going back, for their numbers and influence were increasing.

STANDARDIZATION OF PIPE FLANGES AND FLANGED FITTINGS.

By Mr. ROBERT E. ATKINSON, *Associate Member*, of Leicester.

The lack of universal agreement amongst engineers respecting dimensions of flanges for steam-pipes, valves, &c., and general over-all measurements of flanged fittings and connections, is a source of much inconvenience and expense, which could be largely prevented by the adoption of satisfactory standard dimensions for these goods. The President of this Institution, in his able and interesting Address * to the Members in April 1901, emphasized the importance of this subject and indicated its capabilities. It is satisfactory to observe as a sign of the times that engineers especially fully recognise the benefits to be conferred by standardization; for by its means not only would the cost of production be reduced, but the efficiency of manufacture would also be increased.

The want of interchangeability is keenly realised in any class of work, when breakdowns occur. Delays are frequently involved in obtaining renewals of valves or fittings, and in the case of an electrical power installation this may involve serious loss. When public institutions such as hospitals are concerned, the delay may prove more disastrous than financial loss. Users will at once recognise that, without a common standard, their purchasing area is greatly restricted. Owing to the varied requirements as to the sizes of flanges, methods of drilling, &c., manufacturers find inconvenience and difficulty in speedy production, as it is impossible to commit themselves to the large expense necessary to produce high-class patterns and up-to-date machinery, or to carry goods in stock ready for delivery.

---

* Proceedings 1901, page 443.

In connection with the preparation of this Paper, communications have been addressed to upwards of 200 British and foreign firms manufacturing valves and other kinds of flanged fittings; approximately 120 of these have replied sending Tables of standards used by them, and expressing a sincere desire to see some universal standard adopted. Broadly speaking, the variation in the practice of these 120 firms was comparatively slight, but in no two cases did the Tables sent agree in every particular, there being just sufficient variation to prevent the requisite interchangeability. There was, however, a generally expressed desire for the adoption of a uniform standard.

In some other countries this question has received attention for many years, and has been the subject of exhaustive reports. In 1894 the American Society of Mechanical Engineers, together with the Master Steam and Hot Water Fitters' Association, appointed a joint committee to deal with it, and in July of that year they presented a report containing a Table of standard flanges,* which was adopted by these societies, and by the principal valve and fitting manufacturers of America, Table I (page 306). The intention of the compilers of this standard was that it should apply for all pressures; but latterly pressures carried on boilers, etc., have increased very rapidly, and it was consequently found that for pressures above 124 lbs. the flanges adopted were too small in diameter, and had an insufficient number of bolts. Recognising these imperfections, Mr. J. C. Melloon, of the General Fire Extinguisher Company, Providence, R.I., U.S.A., in April 1901 called a meeting of the principal valve and fitting manufacturers of America, which resulted in the formation of an additional Table of flanges, to apply to pressures 125 to 250 lbs.,* Table II (page 307). This was adopted unanimously, the date appointed for the commencement of its use being 1st January 1902.

---

* "Bulletin," Master Steam and Hot Water Fitters' Association, July 1894.

A definite movement of the same character has also been made in Germany. In the year 1900 the Society of German Engineers compiled an exceedingly valuable and minute report on standards of pipes and flanges for high-pressure steam.† That part of the report which refers to the flanges is embodied in Table IV (page 309). This Table, however, dealt only with flanges for a pressure of 8 to 20 atmospheres (118 to 294 lbs.); but some time previously this Society, with the Society of Gas and Steam Fitters, jointly compiled a Table for flanges of pipes for pressures up to 8 atmospheres (118 lbs.), Table III (page 308). So far as can be ascertained from enquiries in other countries, no definite standard has been formulated elsewhere; but enquiries have elicited from various parts strong expressions of opinion in favour of standardization, as the following interesting extract from the letter of a French correspondent will sufficiently indicate:—

"Unhappily in France we have no regular standard for flanges. It would certainly be the best thing for all heating and mechanical engineers, if an international standard should be formulated. In our country, where French, American, German and English valves and fittings are simultaneously in trade competition, it is for engineers a true nuisance with the different sizes of flanges."

In Great Britain most of the leading engineering firms use a standard more or less applicable to their own particular requirements. Of these the author has selected four as being representative examples of British practice, Tables V, VI, and VII (pages 310–312).

---

* "Power," November 1901.

† Proceedings of the Society of German Engineers, January 1900.

TABLE I.

Standard Flanges adopted by the American Society of Mechanical Engineers, and the Master Steam and Hot Water Fitters' Association of America, 1894.

For Pressures up to 124 lbs.

Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts. Pressure under 80 lbs.	Size of Bolts. Pressure 80 lbs. and over.	Flange thickness at Hub for Iron Pipe.	Flange thickness at Edge.	Width of Flange Face.
ins.	ins.	ins.		ins.	ins.	ins.	ins.	ins.
2	6	$4\frac{3}{4}$	4	$\frac{1}{2} \times 2$	$\frac{5}{8} \times 2$	1	$\frac{5}{8}$	2
$2\frac{1}{2}$	7	$5\frac{1}{2}$	4	$\frac{1}{2} \times 2\frac{1}{4}$	$\frac{5}{8} \times 2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{11}{16}$	$2\frac{1}{4}$
3	$7\frac{1}{2}$	6	4	$\frac{1}{2} \times 2\frac{1}{2}$	$\frac{5}{8} \times 2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{4}$
$3\frac{1}{2}$	$8\frac{1}{2}$	7	4	$\frac{1}{2} \times 2\frac{1}{2}$	$\frac{5}{8} \times 2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{13}{16}$	$2\frac{1}{2}$
4	9	$7\frac{1}{2}$	4	$\frac{5}{8} \times 2\frac{3}{4}$	$\frac{3}{4} \times 2\frac{3}{4}$	$1\frac{3}{8}$	$\frac{15}{16}$	$2\frac{1}{2}$
$4\frac{1}{2}$	$9\frac{1}{4}$	$7\frac{3}{4}$	8	$\frac{5}{8} \times 3$	$\frac{3}{4} \times 3$	$1\frac{3}{8}$	$\frac{15}{16}$	$2\frac{3}{8}$
5	10	$8\frac{1}{2}$	8	$\frac{5}{8} \times 3$	$\frac{3}{4} \times 3$	$1\frac{1}{2}$	$\frac{15}{16}$	$2\frac{1}{2}$
6	11	$9\frac{1}{2}$	8	$\frac{5}{8} \times 3$	$\frac{3}{4} \times 3$	$1\frac{1}{2}$	1	$2\frac{1}{2}$
7	$12\frac{1}{2}$	$10\frac{3}{4}$	8	$\frac{5}{8} \times 3\frac{1}{4}$	$\frac{3}{4} \times 3\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$2\frac{3}{4}$
8	$13\frac{1}{2}$	$11\frac{3}{4}$	8	$\frac{5}{8} \times 3\frac{1}{2}$	$\frac{3}{4} \times 3\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$2\frac{3}{4}$
9	15	$13\frac{1}{4}$	12	$\frac{5}{8} \times 3\frac{1}{2}$	$\frac{3}{4} \times 3\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{8}$	3
10	16	$14\frac{1}{4}$	12	$\frac{3}{4} \times 3\frac{5}{8}$	$\frac{7}{8} \times 3\frac{5}{8}$	2	$1\frac{3}{16}$	3
12	19	17	12	$\frac{3}{4} \times 3\frac{3}{4}$	$\frac{7}{8} \times 3\frac{3}{4}$	2	$1\frac{1}{4}$	$3\frac{1}{2}$
14	21	$18\frac{3}{4}$	12	$\frac{7}{8} \times 4\frac{1}{4}$	$1 \times 4\frac{1}{4}$	2	$1\frac{3}{8}$	$3\frac{1}{2}$
15	$22\frac{1}{4}$	20	16	$\frac{7}{8} \times 4\frac{1}{4}$	$1 \times 4\frac{1}{4}$	2	$1\frac{3}{8}$	$3\frac{5}{8}$
16	$23\frac{1}{2}$	$21\frac{1}{4}$	16	$\frac{7}{8} \times 4\frac{1}{4}$	$1 \times 4\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{7}{16}$	$3\frac{3}{4}$
18	25	$22\frac{3}{4}$	16	$1 \times 4\frac{3}{4}$	$1\frac{1}{8} \times 4\frac{3}{4}$	—	$1\frac{9}{16}$	$3\frac{1}{2}$
20	$27\frac{1}{2}$	25	20	1×5	$1\frac{1}{8} \times 5$	—	$1\frac{11}{16}$	$3\frac{3}{4}$

TABLE II.

Standard Flanges adopted in America, 1st January 1902.

For Pressures 125 lbs. to 250 lbs.

Diameter of Pipe.	Diameter of Flange.	Thickness of Flange.	Diameter of Bolt Circle.	Number of Bolts.	Size of Bolts.
inches.	inches.	inches.	inches.		inches.
2	6½	⅞	5	4	⅝
2½	7½	1	5⅞	4	¾
3	8¼	1⅛	6⅝	8	⅝
3½	9	1 3/16	7¼	8	⅝
4	10	1¼	7⅞	8	¾
4½	10½	1 5/16	8½	8	¾
5	11	1⅜	9¼	8	¾
6	12½	1 7/16	10⅝	12	¾
7	14	1½	11⅞	12	⅞
8	15	1⅝	13	12	⅞
9	16	1¾	14	12	⅞
10	17½	1⅞	16¼	16	⅞
12	20	2	17¾	16	⅞
14	22½	2⅛	20	20	⅞
15	23½	2 3/16	21	20	1
16	25	2¼	22½	20	1
18	27	2⅜	24½	24	1
20	29½	2½	26¾	24	1⅛
22	31½	2⅝	28¾	28	1⅛
24	34	2¾	31¼	28	1⅛

TABLE III.

Standard Flanges compiled by the Association of German Engineers and the Association of Gas, Hot Water and Steam Fitters.

For Steam Pressures up to 118 lbs. (8 Atmospheres).

Inside Diameter of Pipe.		Diameter of Flange.		Diameter of Bolt Circle.		Cir. Pitch of Bolts.		No. of Bolts.	Size of Bolts.
mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.		ins.
40	$1\frac{9}{16}$	140	$5\frac{1}{2}$	110	$4\frac{3}{8}$	87	$3\frac{7}{16}$	4	$\frac{1}{2}$
50	$1\frac{31}{32}$	160	$6\frac{5}{16}$	125	$4\frac{15}{16}$	98	$3\frac{7}{8}$	4	$\frac{5}{8}$
60	$2\frac{3}{8}$	175	$6\frac{7}{8}$	135	$5\frac{5}{16}$	106	$4\frac{3}{16}$	4	$\frac{5}{8}$
70	$2\frac{3}{4}$	185	$7\frac{5}{16}$	145	$5\frac{25}{32}$	114	$4\frac{1}{2}$	4	$\frac{5}{8}$
80	$3\frac{5}{32}$	200	$7\frac{7}{8}$	160	$6\frac{5}{16}$	125	$4\frac{15}{16}$	4	$\frac{5}{8}$
90	$3\frac{17}{32}$	215	$8\frac{15}{32}$	170	$6\frac{11}{16}$	131	$5\frac{7}{32}$	4	$\frac{5}{8}$
100	$3\frac{15}{16}$	230	$9\frac{1}{16}$	180	$7\frac{1}{8}$	140	$5\frac{1}{2}$	4	$\frac{3}{4}$
125	$4\frac{15}{16}$	260	$10\frac{1}{4}$	210	$8\frac{1}{4}$	165	$6\frac{15}{32}$	4	$\frac{3}{4}$
150	$5\frac{15}{16}$	290	$11\frac{7}{16}$	240	$9\frac{7}{16}$	125	$4\frac{15}{16}$	6	$\frac{3}{4}$
175	$6\frac{7}{8}$	320	$12\frac{19}{32}$	270	$10\frac{5}{8}$	141	$5\frac{9}{16}$	6	$\frac{3}{4}$
200	$7\frac{7}{8}$	350	$13\frac{3}{4}$	300	$11\frac{13}{16}$	157	$6\frac{3}{16}$	6	$\frac{3}{4}$
225	$8\frac{7}{8}$	370	$13\frac{3}{4}$	320	$12\frac{19}{32}$	166	$6\frac{9}{16}$	6	$\frac{3}{4}$
250	$9\frac{7}{8}$	400	$15\frac{3}{4}$	350	$13\frac{3}{4}$	136	$5\frac{13}{32}$	8	$\frac{3}{4}$
275	$10\frac{13}{16}$	425	$16\frac{3}{4}$	375	$14\frac{3}{4}$	147	$5\frac{13}{16}$	8	$\frac{3}{4}$
300	$11\frac{13}{16}$	450	$17\frac{3}{4}$	400	$15\frac{3}{4}$	157	$6\frac{3}{16}$	8	$\frac{3}{4}$
325	$12\frac{13}{16}$	490	$19\frac{9}{32}$	435	$17\frac{1}{8}$	136	$5\frac{11}{32}$	10	$\frac{7}{8}$
350	$13\frac{13}{16}$	520	$20\frac{15}{32}$	465	$18\frac{5}{16}$	146	$5\frac{13}{16}$	10	$\frac{7}{8}$
375	$14\frac{13}{16}$	550	$21\frac{21}{32}$	495	$19\frac{1}{2}$	155	$6\frac{1}{8}$	10	$\frac{7}{8}$
400	$15\frac{3}{4}$	575	$22\frac{5}{8}$	520	$20\frac{15}{16}$	166	$6\frac{9}{16}$	10	$\frac{7}{8}$
425	$16\frac{3}{4}$	600	$23\frac{5}{8}$	545	$21\frac{9}{16}$	144	$5\frac{11}{16}$	12	$\frac{7}{8}$
450	$17\frac{3}{4}$	630	$24\frac{13}{16}$	570	$22\frac{17}{32}$	150	$5\frac{15}{16}$	12	$\frac{7}{8}$
475	$18\frac{3}{4}$	655	$25\frac{25}{32}$	600	$23\frac{5}{8}$	157	$6\frac{3}{16}$	12	$\frac{7}{8}$
500	$19\frac{11}{16}$	680	$26\frac{3}{4}$	625	$24\frac{5}{8}$	163	$6\frac{7}{16}$	12	$\frac{7}{8}$
550	$21\frac{21}{32}$	740	$29\frac{1}{8}$	675	$26\frac{5}{8}$	152	6	14	1
600	$23\frac{5}{8}$	790	$31\frac{1}{8}$	725	$28\frac{9}{16}$	141	$5\frac{9}{16}$	16	1
650	$25\frac{19}{32}$	840	$33\frac{1}{16}$	775	$30\frac{1}{2}$	134	$5\frac{5}{16}$	18	1
700	$27\frac{9}{16}$	900	$35\frac{7}{16}$	830	$32\frac{11}{16}$	144	$5\frac{21}{32}$	18	1
750	$29\frac{1}{2}$	950	$37\frac{13}{32}$	880	$34\frac{3}{8}$	138	$5\frac{7}{16}$	20	1

TABLE IV.

Standard Flanges compiled by
the Association of German Engineers in 1900.

For Steam Pressures 118 lbs. to 294 lbs. (8 to 20 Atmospheres)

Inside Diameter of Pipe.		Diameter of Flange.		Diameter of Bolt Circle.		Cir. Pitch of Bolts.		No. of Bolts.	Size of Bolts.
mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.		ins.
30	$1\frac{3}{16}$	125	$4\frac{15}{16}$	95	$3\frac{3}{4}$	50	$1\frac{31}{32}$	6	$\frac{1}{2}$
40	$1\frac{9}{16}$	140	$5\frac{1}{2}$	110	$4\frac{3}{8}$	57	$2\frac{9}{32}$	6	$\frac{1}{2}$
50	$1\frac{31}{32}$	160	$6\frac{5}{16}$	125	$4\frac{15}{16}$	63	$2\frac{19}{32}$	6	$\frac{5}{8}$
60	$2\frac{3}{8}$	175	$6\frac{7}{8}$	135	$5\frac{5}{16}$	70	$2\frac{25}{32}$	6	$\frac{5}{8}$
70	$2\frac{3}{4}$	185	$7\frac{5}{16}$	145	$5\frac{25}{32}$	76	3	6	$\frac{5}{8}$
80	$3\frac{5}{32}$	200	$7\frac{7}{8}$	160	$6\frac{5}{16}$	84	$3\frac{5}{16}$	6	$\frac{3}{4}$
90	$3\frac{17}{32}$	220	$8\frac{21}{32}$	180	$7\frac{1}{8}$	95	$3\frac{3}{4}$	6	$\frac{3}{4}$
100	$3\frac{15}{16}$	240	$9\frac{7}{16}$	190	$7\frac{1}{2}$	100	$3\frac{15}{16}$	6	$\frac{3}{4}$
125	$4\frac{15}{16}$	270	$10\frac{5}{8}$	220	$8\frac{21}{32}$	85	$3\frac{3}{8}$	8	$\frac{3}{4}$
150	$5\frac{15}{16}$	300	$11\frac{13}{16}$	250	$9\frac{7}{8}$	98	$3\frac{7}{8}$	8	$\frac{7}{8}$
175	$6\frac{7}{8}$	330	$13\frac{1}{16}$	280	11	87	$3\frac{7}{16}$	10	$\frac{7}{8}$
200	$7\frac{7}{8}$	360	$14\frac{3}{4}$	310	$12\frac{3}{16}$	81	$3\frac{3}{16}$	12	$\frac{7}{8}$
225	$8\frac{7}{8}$	390	$15\frac{3}{8}$	340	$13\frac{7}{16}$	88	$3\frac{1}{2}$	12	1
250	$9\frac{7}{8}$	420	$16\frac{9}{16}$	370	$14\frac{9}{16}$	96	$3\frac{25}{32}$	12	1
275	$10\frac{13}{16}$	450	$17\frac{3}{4}$	400	$15\frac{3}{4}$	88	$3\frac{1}{2}$	14	1
300	$11\frac{13}{16}$	480	$18\frac{15}{16}$	430	$16\frac{15}{16}$	84	$3\frac{5}{16}$	16	1
325	$12\frac{13}{16}$	520	$20\frac{15}{16}$	465	$18\frac{5}{16}$	89	$3\frac{9}{16}$	16	$1\frac{1}{8}$
350	$13\frac{13}{16}$	550	$21\frac{21}{32}$	495	$19\frac{3}{8}$	96	$3\frac{13}{16}$	16	$1\frac{1}{8}$
375	$14\frac{13}{16}$	580	$22\frac{13}{16}$	525	$20\frac{5}{8}$	92	$3\frac{19}{32}$	18	$1\frac{1}{8}$
400	$15\frac{3}{4}$	605	$23\frac{13}{16}$	550	$21\frac{21}{32}$	86	$3\frac{13}{32}$	20	$1\frac{1}{8}$

TABLE V.

Standard Flanges (Plate 29.)

used by

Messrs. J. Hopkinson & Co., Huddersfield.

Diameter of Pipe.	Diameter of Flange.	Thickness of Flange in Steel.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts.
ins.	ins.	ins.	ins.		ins.
½	3½	—	2½	4	7/16
¾	3¾	—	2¾	4	7/16
1	4½	—	3⅜	4	½
1¼	5	—	3⅝	4	½
1½	5½	—	4	4	½
2	{6 6½	⅞	4⅝} 5	4	⅝
2¼	6½	⅞	5	4	⅝
2½	7	⅞	5½	6	⅝
3	8	1	6¼	6	¾
3½	8½	1	6¾	6	¾
4	9	1	7¼	6	¾
4½	9½	1⅛	7¾	6	¾
5	10½	1⅛	8¾	8	¾
6	12	1¼	10	8	¾
7	13½	1⅜	11½	8	¾
8	15	1½	12¾	8	⅞
9	16	1⅝	13¾	10	⅞
10	17	1⅝	14¾	10	⅞
11	18	1⅞	15¾	12	⅞
12	19	1⅞	16¾	12	⅞
13	21	1⅞	18	14	1
14	22	1⅞	19	14	1
15	23	1⅞	20	16	1
16	24	1⅞	21	16	1
17	25	1⅞	22	18	1
18	26	1⅞	23	18	1

Messrs. Dewrance & Co., London.

Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts.
ins.	ins.	ins.		ins.
½	3½	2½	4	⅜
¾	3¾	2¾	4	7/16
1	4½	3¼	4	½
1¼	5	3⅝	4	⅝
1½	5½	4⅛	4	⅝
1¾	5¾	4⅜	4	⅝
2	6	4⅝	4 or 6	⅝
2¼	6½	5	4 or 6	⅝
2½	7	5½	4 or 6	⅝
2¾	7½	5⅞	4 or 6	¾
3	8	6¼	4 or 6	¾
3½	8½	6¾	4 or 6	¾
4	9	7¼	4 or 6	¾
5	10½	8¾	6	¾
6	12	10⅛	8	¾
7	13	11¼	8	¾
8	14½	12⅜	10	¾
9	15½	13⅜	10	¾
10	17	14⅞	12	⅞

TABLE VI.

Standard Flanges used by Messrs. Mather and Platt, Salford Iron Works, Manchester.

(*Plate* 29.)

Working Pressures up to 50 lbs.					Working Pressures up to 100 lbs.					Working Pressures up to 200 lbs.				
Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts.	Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts.	Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	No. of Bolts.	Size of Bolts.
ins.	ins.	ins.		ins.	ins.	ins.	ins.		ins.	ins.	ins.	ins.		ins.
¾	4	3	—	—	2	6½	5	4	⅝	2	6½	5	6	⅝
1	4½	3¼	—	—	2½	7	5½	4	⅝	2½	7	5½	6	⅝
1¼	5	3¾	—	—	3	7½	5⅞	4	⅝	3	7½	5⅞	6	⅝
1½	5½	4¼	—	—	3½	8	6½	4	⅝	3½	8	6½	8	⅝
1¾	6	4¾	—	—	4	9	7⅜	6	⅝	4	9	7⅜	8	⅝
2	6½	5	4	½	4½	9½	7⅞	6	⅝	4½	9½	7⅞	8	⅝
2½	7	5½	4	½	5	10	8¼	6	¾	5	10	8¼	8	¾
3	7½	5⅞	4	9/16	6	12	10⅛	8	¾	6	12	10⅛	12	¾
3½	8	6½	4	9/16	7	13	11⅛	8	¾	7	13	11⅛	12	¾
4	9	7⅜	4	⅝	8	14	12	8	¾	8	14	12	12	¾
4½	9½	7⅞	4	⅝	9	16	13½	8	¾	9	16	13½	16	¾
5	10	8¼	4	¾	10	17	14¾	12	¾	10	17	14¾	16	¾
					11	18	15¾	12	¾	11	18	15¾	16	⅞
6	12	10⅛	6	¾	12	19	16¾	12	¾	12	19	16¾	16	⅞
7	13	11⅛	6	¾	13	20	17¾	12	¾	13	20	17¾	20	⅞
8	14	12	6	¾	14	21	18¾	12	¾	14	21	18¾	20	⅞
9	16	13½	6	⅞	15	23	20¾	12	¾					
10	17	14¾	8	⅞	16	24	21½	16	¾					
11	18	15¾	8	⅞	17	25	22¼	16	¾					
12	19	16¾	8	⅞	18	26	23¼	16	⅞					
13	20	17¾	8	⅞	19	27	24¼	16	⅞					
14	21	18¾	10	⅞	20	28	25½	16	⅞					
15	23	20¾	10	⅞	21	29	26½	20	⅞					
16	24	21½	10	1	22	30	27½	20	⅞					
17	25	22¼	10	1	23	31	28½	20	⅞					
18	26	23¼	10	1	24	32	29½	20	1					

TABLE VII.

Standard Flanges adopted by Messrs. James Russell and Sons, Crown Tube Works, Wednesbury.

Inside Diameter of Pipe.	Outside Diameter of Flange.	Inside Diameter of Pipe.	Outside Diameter of Flange.
inches.	inches.	inches.	inches.
½	3½	5	10
¾	3¾	5½	10½
1	4½	6	11½
1¼	5	6½	12½
1½	5½	7	13
1¾	5½	7½	13½
2	6	8	14
2¼	6½	8½	14½
2½	7	9	15
2¾	7½	9½	15½
3	8	10	16½
3¼	8½	10½	17
3½	8½	11	17½
3¾	9	11½	18
4	9	12	18½
4½	9½		

In further reference to the American Table (page 307), it will be noted that the diameters of flanges for pressures above 125 lbs. are larger than those for lower-pressures. To the author this does not appear to be necessary, and, as it prevents the use of a valve or fitting constructed for the higher pressures in connection with low-pressure pipes and flanges, it is likely to lead to confusion. The high-pressure flanges appear to have been made larger, and the diameter of the bolt circles correspondingly large, in order to provide for the use of very thick material in the pipes. It, however, seems practicable to reduce the diameter of these high-pressure flanges to such an extent that the low-pressure flanges might be increased without serious objection, and thus make one standard common to all pressures.

With regard to the bolt-holes, it will be observed that in the standards of both 1894 and 1901 the number of bolts in a flange is in every case divisible by four, and that the bolt-holes are not drilled on the centre line of a valve or fitting, but symmetrically on each side of it. In the standard for pressures up to 125 lbs. four bolts in a flange are considered sufficient for pipes up to and including 4 inches inside diameter; but for pressures above 125 lbs. four bolts are used for the flanges for 2-inch and $2\frac{1}{2}$-inch pipes, and eight bolts for flanges on 3-inch to 5-inch pipes inclusive. It however appears to the author that these standards would have been more valuable, if the number of bolts as well as the diameters of flanges had been the same for each diameter of pipe, and alike for both high and low pressures.

As to the standards adopted by the Society of German Engineers, there is again a lack of uniformity in the outside diameter of flanges, and in the number of bolts used for various pressures. The flange diameters are the same in both standards for all pressures and for all pipes up to those having an inside diameter of 80 mm., but beyond these, though the difference is comparatively slight, it is nevertheless sufficient to prevent interchangeability, as will be seen by reference to the Tables (pages 308–309). To take as an instance a pipe 150 mm. (approximately 6 inches), inside diameter, in the low-pressure standard the flange is 290 mm. ($11\frac{7}{16}$ inches) diameter, whilst the high-pressure standard flange is 300 mm. ($11\frac{13}{16}$ inches) diameter for the same size pipe. It will also be observed that they have not considered it expedient to adopt the principle, that the number of bolts should be divisible by four, although there is evidence to show that the advisability of this course was pointed out to the committee of the society referred to. Messrs. Schäffer and Budenberg—who have works in Germany, England, and America—prepared a Table which the author understands they submitted to the said committee, and in which the bolts are arranged so that in every case the number is divisible by four, Table VIII (page 315). The following is an extract from the report of the Society of German Engineers regarding this:—

"It was suggested that the number of bolts to be used should be divided by four. Such suggestion would have led to unsuitable measurements of flanges, and consequently the disadvantages would have exceeded the advantages expected to be derived. As moreover such a rule has not been adopted with respect to the standards for the flange pipes for a low pressure, the Committee abstain from assenting to this suggestion." *

Judging from these remarks the Association of German Engineers, in compiling their standard of flanges for pressures of 8 to 20 atmospheres (118 to 294 lbs.), appear to have been influenced to a considerable degree by the standard which was already in existence with them for pressures below 8 atmospheres (118 lbs.), and generally to have formulated the standard on a purely theoretical basis, without sufficient regard to practical considerations. It is said that difficulty is experienced with these German standards in general use, mainly on account of the number of bolts not being divisible by four, and that valves and other fittings must be kept in stock undrilled, until the manufacturer receives an order from the user, giving the exact position of the holes, which may or may not be required to be drilled on the centre line of the valve spindle, or fitting. It may be added that in speaking of German practice it is understood that the pressures are "absolute," while the English and American are gauge pressures.

---

* Proceedings of the Society of German Engineers, January 1900.

TABLE VIII.

Standard Flanges proposed by Messrs. Schäffer and Budenberg to the Society of German Engineers, but not approved by them. (*January* 1900.)

Diameter of Pipe.		Diameter of Flange.		Thickness of Flange.		Centres of Bolt-Holes.		Thickness of Bolts.	Number of Bolts.	
mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	ins.	20 Atm. (294 lbs.)	12 Atm. (176·4 lbs.)
20	$\frac{3}{4}$	95	$3\frac{3}{4}$	18	$\frac{5}{8}$	70	$2\frac{3}{4}$	$\frac{3}{8}$	4	4
25	1	110	$4\frac{3}{8}$	18·5	$\frac{21}{32}$	80	$3\frac{5}{32}$	,,	,,	,,
30	$1\frac{3}{16}$	120	$4\frac{3}{4}$	19	$\frac{11}{16}$	90	$3\frac{17}{32}$	,,	,,	,,
35	$1\frac{3}{8}$	130	$5\frac{1}{8}$	19·5	$\frac{23}{32}$	100	$3\frac{15}{16}$	,,	,,	,,
40	$1\frac{9}{16}$	140	$5\frac{1}{2}$	20	$\frac{3}{4}$	110	$4\frac{3}{8}$	$\frac{1}{2}$	,,	,,
45	$1\frac{3}{4}$	150	$5\frac{15}{16}$	20·5	$\frac{25}{32}$	115	$4\frac{9}{16}$	,,	,,	,,
50	$1\frac{31}{32}$	160	$6\frac{5}{16}$	21	$\frac{13}{16}$	125	$4\frac{15}{16}$	$\frac{5}{8}$	,,	,,
55	$2\frac{1}{8}$	170	$6\frac{11}{16}$	21·5	$\frac{27}{32}$	135	$5\frac{5}{16}$	,,	,,	,,
60	$2\frac{3}{8}$	175	$6\frac{7}{8}$	22	$\frac{7}{8}$	140	$5\frac{1}{2}$	,,	,,	,,
65	$2\frac{9}{16}$	180	$7\frac{1}{8}$	22	$\frac{7}{8}$	145	$5\frac{25}{32}$	,,	,,	,,
70	$2\frac{3}{4}$	185	$7\frac{5}{16}$	22·5	$\frac{7}{8}$	150	$5\frac{15}{16}$	,,	,,	,,
80	$3\frac{5}{32}$	200	$7\frac{7}{8}$	23	$\frac{29}{32}$	165	$6\frac{1}{2}$	,,	8	,,
90	$3\frac{17}{32}$	215	$8\frac{7}{16}$	23·5	$\frac{15}{16}$	175	$6\frac{7}{8}$	,,	,,	,,
100	$3\frac{15}{16}$	230	$9\frac{1}{16}$	24	$\frac{31}{32}$	190	$7\frac{1}{2}$	,,	,,	,,
110	$4\frac{3}{8}$	245	$9\frac{5}{8}$	25	1	205	$8\frac{1}{16}$	$\frac{3}{4}$	,,	,,
120	$4\frac{3}{4}$	260	$10\frac{1}{4}$	26	$1\frac{1}{32}$	215	$8\frac{7}{16}$	,,	,,	,,
125	$4\frac{15}{16}$	260	$10\frac{1}{4}$	26	$1\frac{1}{32}$	215	$8\frac{7}{16}$	,,	,,	,,
130	$5\frac{1}{8}$	275	$10\frac{13}{16}$	27	$1\frac{1}{16}$	230	$9\frac{1}{16}$	,,	,,	8
140	$5\frac{1}{2}$	285	$11\frac{3}{16}$	27	$1\frac{1}{16}$	240	$9\frac{7}{16}$	,,	,,	,,
150	$5\frac{15}{16}$	300	$11\frac{13}{16}$	28	$1\frac{3}{32}$	250	$9\frac{7}{8}$	$\frac{7}{8}$	,,	,,
175	$6\frac{7}{8}$	330	$13\frac{1}{16}$	30	$1\frac{3}{16}$	280	11	,,	,,	,,
200	$7\frac{7}{8}$	360	$14\frac{3}{4}$	32	$1\frac{1}{4}$	310	$12\frac{3}{16}$	,,	12	,,
225	$8\frac{7}{8}$	400	$15\frac{3}{4}$	34	$1\frac{11}{32}$	345	$13\frac{5}{8}$	1	,,	,,
250	$9\frac{7}{8}$	430	$16\frac{15}{16}$	35	$1\frac{3}{8}$	375	$14\frac{13}{16}$	,,	,,	,,
275	$10\frac{13}{16}$	455	$17\frac{15}{16}$	37	$1\frac{15}{32}$	400	$15\frac{3}{4}$	,,	16	12
300	$11\frac{13}{16}$	490	$19\frac{3}{16}$	40	$1\frac{9}{16}$	430	$16\frac{15}{16}$	,,	,,	,,
325	$12\frac{13}{16}$	525	$20\frac{5}{8}$	41	$1\frac{19}{32}$	465	$18\frac{5}{16}$	$1\frac{1}{8}$	,,	,,
350	$13\frac{13}{16}$	555	$21\frac{7}{8}$	42	$1\frac{21}{32}$	495	$19\frac{3}{8}$	,,	20	,,
375	$14\frac{13}{16}$	595	$23\frac{7}{16}$	44	$1\frac{11}{16}$	530	$20\frac{7}{8}$	$1\frac{1}{4}$	,,	,,
400	$15\frac{3}{4}$	620	$24\frac{3}{8}$	47	$1\frac{27}{32}$	555	$21\frac{7}{8}$	,,	,,	16
425	$16\frac{3}{4}$	655	$25\frac{3}{4}$	50	$1\frac{31}{32}$	585	23	,,	24	,,
450	$17\frac{3}{4}$	685	27	52	$2\frac{1}{16}$	615	$24\frac{7}{32}$	,,	,,	,,
475	$18\frac{3}{4}$	715	$28\frac{1}{8}$	53	$2\frac{3}{32}$	645	$25\frac{3}{8}$	$1\frac{3}{8}$	,,	,,
500	$19\frac{11}{16}$	750	$29\frac{1}{2}$	55	$2\frac{1}{8}$	675	$26\frac{9}{16}$	,,	,,	,,
550	$21\frac{21}{32}$	830	$32\frac{11}{16}$	59	$2\frac{11}{32}$	750	$29\frac{1}{2}$	$1\frac{1}{2}$	,,	,,
600	$23\frac{5}{8}$	900	$35\frac{7}{16}$	63	$2\frac{1}{2}$	810	$31\frac{7}{8}$	$1\frac{5}{8}$	,,	,,

In the general course of English practice this difficulty as to the number of bolt-holes is equally apparent, six, ten and fourteen bolts being used for various sizes, in disregard of the advantage of the principle of the divisibility by four—a principle which has been adopted with great success for some years by the firm with which the author is connected. On Tables IX, X, and XI (pages 317–319) will be found particulars of the dimensions of flanges designed to meet the difficulties already indicated. These Tables show flanges adapted to working pressures as follows:—

No. 1. 0 to 50 lbs. steam pressure (Table IX).
No. 2. 51 to 150 „ „ „ („ X).
No. 3. 151 to 250 „ „ „ („ XI).

Drawings have been prepared, showing proposed flanges for pipes from ½ inch to 24 inches internal diameter inclusive, Plates 31 to 36. Wrought-iron or steel pipes and flanges being commonly used for pressures exceeding 100 lbs., sections of flanges constructed of wrought-iron or steel as well as cast-iron are shown on these Plates. Drawings of various forms of flanged joints are also given, to which the standard proposed is applicable, some of these being constructed of copper, brass, wrought and cast steel, and other metals, Plates 37 to 39, and Table XII (page 329). In preparing this standard, the following have been adopted as guiding principles:—

Uniformity in the outside diameter of flanges for varying conditions.

Uniformity in the number of bolt-holes, and diameter of bolt circle.

The number of bolts should in all cases be divisible by four.

The fact that uniformity is desirable will be appreciated, when it is realised that wrought steel and iron pipes are often connected with cast steel and cast-iron valves and fittings, and cast-iron pipes with valves and fittings of gun-metal, etc.; and further that flanges are attached to pipes by being screwed, brazed, welded, and riveted. The first point to take into account, if uniformity is to be obtained, is that the flange must be large enough in diameter to allow of a

TABLE IX.

Standard Flanges (any metal) adopted by the Author's Firm.

(*Plates* 31 *to* 36 *and Fig.* 71, *page* 323.)

0 to 50 lbs. Steam Pressure. 0 to 75 lbs. Water Pressure.

Inside Diameter of Pipe.		Diameter of Flange.		Normal Thickness of Flange in C. Iron.	Width of Flange Face.	Diameter of Bolt Circle.	Circum. Pitch of Bolts.	No. of Bolts.	Size of Bolts.	Stress on each Bolt per square inch at bottom of Thread at 50 lbs.
ins.	mm.	ins.	mm.	ins.	ins.	ins.	ins.		ins.	lbs.
½	12·70	3½	88·90	7/16	1½	2½	1·96	4	⅜	37
¾	19·05	4	101·60	7/16	1⅝	3	2·35	4	⅜	81
1	25·40	4½	114·30	½	1¾	3⅜	2·65	4	⅜	144
1¼	31·75	5	127·00	½	1⅞	3¾	2·94	4	⅜	226
1½	38·10	5½	139·70	½	2	4¼	3·33	4	⅜	326
2	50·80	6½	165·11	⅝	2¼	5	3·92	4	½	328
2½	63·50	7	177·80	⅝	2¼	5½	4·31	4	½	510
3	76·20	8	203·20	⅝	2½	6	2·35	8	½	364
3½	88·90	8½	215·90	¾	2½	6¾	2·65	8	⅝	300
4	101·60	9	228·60	¾	2½	7⅜	2·89	8	⅝	387
4½	114·30	10	254·00	⅞	2¾	8¼	3·23	8	⅝	491
5	127·00	10½	266·70	⅞	2¾	8¾	3·43	8	⅝	606
6	152·40	12	304·80	⅞	3	10	3·92	8	⅝	864
7	177·80	13½	342·90	1	3¼	11½	4·51	8	⅝	1177
8	203·20	14½	368·30	1	3¼	12½	3·27	8	⅝	1034
9	228·60	16	406·40	1	3½	14	3·66	12	⅝	1303
10	254·00	17	431·80	1⅛	3½	14¾	3·86	12	⅝	1608
11	279·39	18½	469·90	1⅛	3¾	16¼	4·25	12	¾	1305
12	304·79	19½	495·30	1⅛	3¾	16¾	3·29	16	⅝	1733
13	330·19	21	533·40	1⅛	4	18¼	3·58	16	¾	1365
14	355·59	22	558·80	1¼	4	19	3·73	16	¾	1584
15	381·00	23	584·20	1¼	4	20	3·92	16	¾	1818
16	406·40	24	609·60	1¼	4	21	4·12	16	¾	2068
17	431·80	25	635·00	1¼	4	22	3·45	20	¾	1891
18	457·20	26	660·40	1¼	4	23	3·61	20	¾	2120
20	508·00	28	711·20	1¼	4	25½	4·00	20	¾	2616
22	558·80	30	762·00	1⅜	4	27½	3·60	24	¾	2602
24	609·60	32	812·80	1⅜	4	29½	3·86	24	¾	3097

TABLE X.

Standard Flanges (any metal) adopted by the Author's Firm.
(See Plates 31 *to* 36 *and Fig.* 71, *page* 323.)

51 to 150 lbs. Steam Pressure. 76 to 225 lbs. Water Pressure.

Inside Diameter of Pipe.		Diameter of Flange.		Normal Thickness of Flange in C. Iron.	Width of Flange Face.	Diameter of Bolt Circle.	Circum. Pitch of Bolts.	No. of Bolts.	Size of Bolts.	Stress on each Bolt per square inch at bottom of Thread at 150 lbs.
ins.	mm.	ins.	mm.	ins.	ins.	ins.	ins.		ins.	lbs.
½	12·70	3½	88·90	9/16	1½	2½	1·96	4	⅜	110
¾	19·05	4	101·60	9/16	1⅝	3	2·35	4	⅜	242
1	25·40	4½	114·30	⅝	1¾	3⅜	2·65	4	½	235
1¼	31·75	5	127·00	⅝	1⅞	3¾	2·94	4	½	367
1½	38·10	5½	139·70	¾	2	4¼	3·33	4	½	529
2	50·80	6½	165·11	¾	2¼	5	3·92	4	⅝	572
2½	63·50	7	177·80	⅞	2¼	5½	4·31	4	⅝	918
3	76·20	8	203·20	⅞	2½	6	2·35	8	½	1093
3½	88·90	8½	215·90	⅞	2½	6¾	2·65	8	⅝	900
4	101·60	9	228·60	1	2½	7⅜	2·89	8	⅝	1162
4½	114·30	10	254·00	1	2¾	8¼	3·23	8	⅝	1473
5	127·00	10½	266·70	1	2¾	8¾	3·43	8	⅝	1818
6	152·40	12	304·80	1⅛	3	10	3·92	8	¾	1746
7	177·80	13½	342·90	1⅛	3¼	11½	4·51	8	¾	2374
8	203·20	14½	368·30	1¼	3¼	12½	3·27	12	⅝	3102
9	228·60	16	406·40	1¼	3½	14	3·66	12	¾	2620
10	254·00	17	431·80	1⅜	3½	14¾	3·86	12	¾	3234
11	279·39	18½	469·90	1½	3¾	16¼	4·25	12	⅞	2826
12	304·79	19½	495·30	1½	3¾	16¾	3·29	16	¾	3487
13	330·19	21	533·40	1⅝	4	18¼	3·58	16	⅞	2958
14	355·59	22	558·80	1⅝	4	19	3·73	16	⅞	3429
15	381·00	23	584·20	1¾	4	20	3·92	16	⅞	3940
16	406·40	24	609·60	1¾	4	21	4·12	16	⅞	4485
17	431·80	25	635·00	1¾	4	22	3·45	20	⅞	4047
18	457·20	26	660·40	1¾	4	23	3·61	20	⅞	4534
20	508·00	28	711·20	1¾	4	25½	4·00	20	⅞	5580
22	558·80	30	762·00	1¾	4	27½	3·60	24	⅞	5700
24	609·60	32	812·80	1¾	4	29½	3·86	24	1	5102

TABLE XI.

Standard Flanges. Steel (cast or wrought) adopted by the Author's Firm.

(See Plates 31 *to* 36 *and Fig.* 71, *page* 323.)

151 to 250 lbs. Steam Pressure. 226 to 375 lbs. Water Pressure.

Inside Diameter of Pipe.		Diameter of Flange.		Normal Thickness of Flange in C. Steel.	Width of Flange Face.	Diameter of Bolt Circle.	Circum. Pitch of Bolts.	No. of Bolts.	Size of Bolts.	Stress on each Bolt per square inch at bottom of Thread at 250 lbs.
ins.	mm.	ins.	mm.	ins.	ins.	ins.	ins.		ins.	lbs.
½	12·70	3½	88·90	¾	1½	2½	1·96	4	½	97
¾	19·05	4	101·60	¾	1⅝	3	2·35	4	½	220
1	25·40	4½	114·30	¾	1¾	3⅜	2·65	4	½	392
1¼	31·75	5	127·00	⅞	1⅞	3¾	2·94	4	⅝	378
1½	38·10	5½	139·70	15/16	2	4¼	3·33	4	⅝	546
2	50·80	6½	165·11	1	2¼	5	3·92	4	⅝	968
2½	63·50	7	177·80	1 1/16	2¼	5½	4·31	4	⅝	1512
3	76·20	8	203·20	1⅛	2½	6	2·35	8	⅝	1081
3½	88·90	8½	215·90	1⅛	2½	6¾	2·65	8	⅝	1483
4	101·60	9	228·60	1 3/16	2½	7⅜	2·89	8	⅝	1917
4½	114·30	10	254·00	1 3/16	2¾	8¼	3·23	8	¾	1635
5	127·00	10½	266·70	1¼	2¾	8¾	3·43	8	¾	2018
6	152·40	12	304·80	1¼	3	10	3·92	8	⅞	2102
7	177·80	13½	342·90	1⅜	3¼	11½	4·51	8	⅞	2862
8	203·20	14½	368·30	1½	3¼	12½	3·27	12	¾	3450
9	228·60	16	406·40	1½	3½	14	3·66	12	⅞	3155
10	254·00	17	431·80	1⅝	3½	14¾	3·86	12	⅞	3893
11	279·39	18½	469·90	1¾	3¾	16¼	4·25	12	1	3576
12	304·79	19½	495·30	1⅞	4	16¾	3·29	16	⅞	4200
13	330·19	21	533·40	1⅞	4	18¼	3·58	16	1	3750
14	355·59	22	558·80	2	4	19	3·73	16	1	4344
15	381·00	23	584·20	2	4	20	3·92	16	1	4985
16	406·40	24	609·60	2	4	21	4·12	16	1	5672
17	431·80	25	635·00	2	4	22	3·45	20	1	5112
18	457·20	26	660·40	2	4	23	3·61	20	1	5737
20	508·00	28	711·20	2¼	4	25½	4·00	20	1	7136
22	558·80	30	762·00	2¼	4	27½	3·60	24	1	7142
24	609·60	32	812·80	2¼	4	29½	3·86	24	1⅛	6732

sufficient thickness of metal to enable the pipe, even if of cast-iron, to withstand the maximum pressure, and still leave space for accommodation of the head and nut of the bolt. As cast-iron is the metal of least tensile strength commonly used in the construction of valves and fittings, it follows that the largest dimensions will be required when this metal is used, with the possible exception of steel and wrought-iron pipes constructed with flanges of angle rings riveted on to the pipe. This latter form of construction has been taken into account, as the details will show, Plates 31 to 36.

By designing the standard flange suitable for a maximum pressure of 250 lbs. it is apparent that, if uniformity is preserved, the flanges for very low pressures will be larger than is necessary for strength; but as a separate standard would otherwise be required for low pressures, it would appear to be better to choose the lesser of two evils, and permit the slight excess of material for the low pressures. It should, however, be borne in mind that this excessive material would occur in the diameter only of the low pressure flange, and that its thickness could be made proportionate to its duty. It should be added that no rigid rule has been laid down for determining the thickness of flanges of various metals for different pressures, as the difficulty of doing this will be apparent when cognizance is taken of the composition and combination of metals employed by different makers and in different countries; but an average thickness of metal suitable for the various pressures is shown in the Tables. These thicknesses have been calculated with an allowance for the tensile breaking strain of 4 tons per square inch, with a minimum factor of safety of 20. This calculation has been based on the assumption that the flanges are flat faced, being those most commonly used, and that, on making the joint, the jointing material shall extend over the entire face of the flange.

Bolts.

The same principle of interchangeability has been adopted with regard to the number and position of bolts, the proposal being that what difference in strength may be required for the varying pressures should be made in the size of the bolts. The author holds the opinion strongly that no standard can be satisfactory, which does not allow for the number of bolts being a multiple of four; without this, interchangeability is impossible. Fig. 69 (page 322) shows the difficulty attending the use of bolts otherwise than upon this principle. In this sketch is shown a stop valve attached to a boiler, and the flange drilled for six bolts. In dotted lines is indicated the valve turned at right angles, from which will be seen the difficulty that arises, and that a new valve would be required if any alteration of position is desired. Bends, tees, and other fittings require to be adjusted to alterations of position; Fig. 70 (page 322) shows a bend connected to a pipe line, and reveals the impossibility of varying its position, as shown in dotted lines, this fact. being due to its having been drilled with six bolt-holes. Thus the difficulty follows that all valves and fittings must be kept in stock undrilled, causing extra labour and expense in handling again in the works when the position of the bolts is definitely decided; or, if the fitting is sent to be fixed to an installation—probably at some distance from a machine shop and proper tools—it involves the necessity of drilling by means of a ratchet brace, or similar appliance. In the case of tee-pieces, the flanges of which have 6, 10, 14, or 18 holes, it would be impossible to set the centre branch vertically, if it had been drilled to suit a horizontal position. Fig. 71 (page 323) shows the position of the bolt-holes in the proposed standard. In every case the nearest holes to the centre lines are arranged equidistant from them. These centre lines would correspond with the centre line of the spindle of a valve, the horizontal and vertical axes of a boiler, an engine, a pump, or other machine, and would be the same for pipes, valves, tees, and fittings. In the case of valves, the top flange or stuffing box is likely to interfere with the insertion of the bolt, and it is therefore not advisable to arrange the holes on the centre lines. The same difficulty is met with in respect to a bend of short radius.

The sizes of bolts have been calculated assuming an average tensile breaking strain of wrought iron at 22 tons to the square inch (as given for Dudley Iron in Professor Unwin's book on "Strength of Materials"), with a factor of safety of six as a minimum. In the smaller bolts, $\frac{3}{8}$-inch, $\frac{1}{2}$-inch and $\frac{5}{8}$-inch, this

Fig. 69.—*Diagram showing Stop Valve on Boiler, and difficulty in changing the position of same when flange is drilled with six holes.*

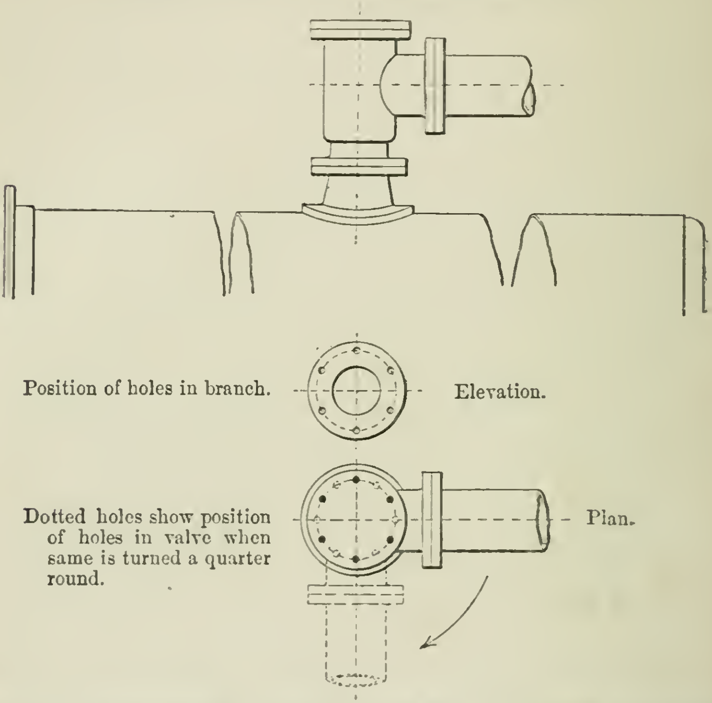
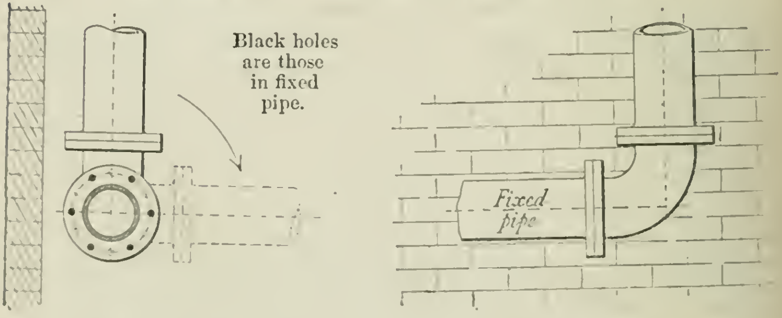

Position of holes in branch.
Elevation.
Dotted holes show position of holes in valve when same is turned a quarter round.
Plan.

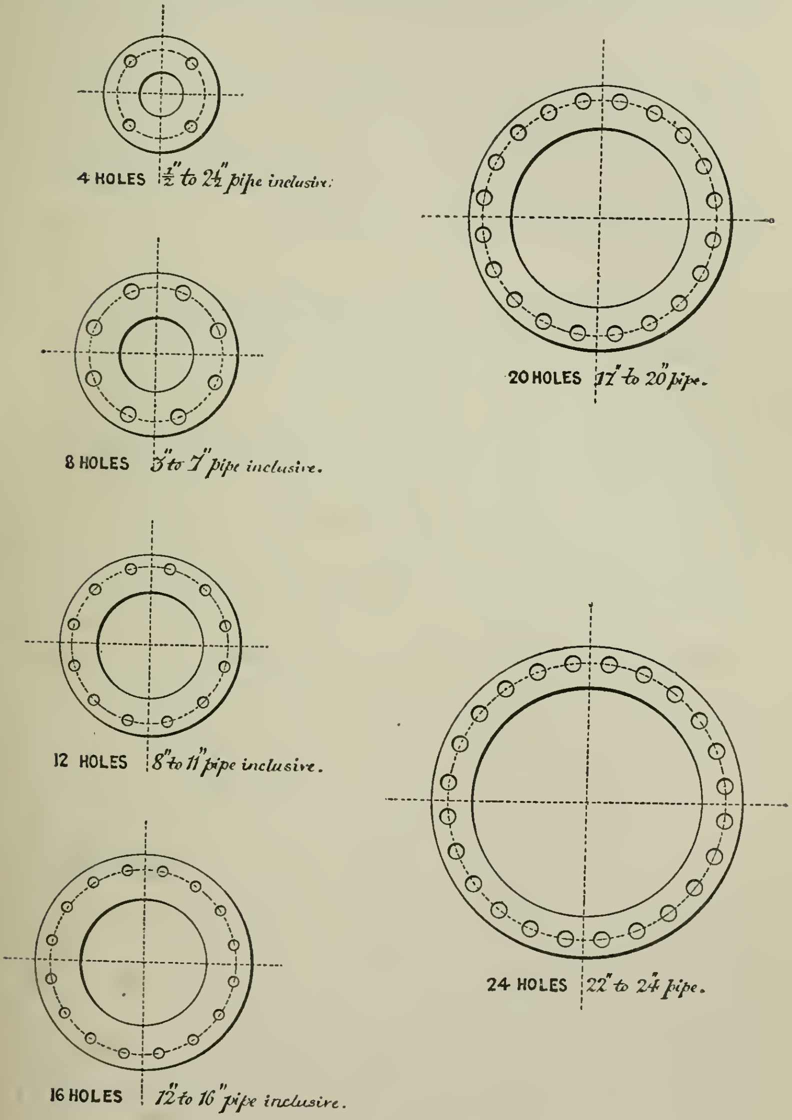
Fig. 70.—*Diagram showing Bend in Steam Main, and difficulty in changing the position of same when flange is drilled with six holes.*



End Elevation. Front Elevation.

Dotted holes show position of holes when same is turned a quarter round.

Fig. 71.—*Diagram showing position of Bolt-Holes in Flanges in the Proposed Standard Designs, Plates* 31 *to* 36, *and Tables* IX, X *and* XI (pages 317-319).



4 HOLES ½" to 2½" pipe inclusive.

8 HOLES 3" to 7" pipe inclusive.

12 HOLES 8" to 11" pipe inclusive.

16 HOLES 12" to 16" pipe inclusive.

20 HOLES 17" to 20" pipe.

24 HOLES 22" to 24" pipe.

factor of safety is much increased, as an altogether disproportionate strain can be placed on the bolt in screwing up. If special high-class bolts are used of a great tensile strength, the diameter can be proportionately reduced, but in average steam-pipe work ordinary merchant bolts are used, and this quality has been taken into consideration in deciding the sizes given in the Table. Professor Goodman has been kind enough to make tests of twelve bolts which were chosen promiscuously from a supply of the quality ordinarily used, and below are the results of his tests :—

Report on Tension Tests of 12 *specimens of Bolts,*
by Professor John Goodman, of the Yorkshire College, Leeds.

Bolt diameter.	Nominal Area at bottom of Thread.	Extensions per cent.	Maximum Stress in tons per square inch.	Breaking Loads in tons.	Remarks.
in.	sq. in.		tons.	tons.	
		(on 3·8″)			
$\frac{7}{8}$	0·42	6·6	29·1	12·20	Broke at bottom of Thread in every case.
,,	,,	7·3	30·5	12·81	
,,	,,	7·3	29·5	12·40	
		(on 3·5″)			
$\frac{3}{4}$	0·30	8·0	33·2	9·95	
,,	,,	7·8	28·3	8·48	
,,	,,	4·7	30·6	9·17	
		(on 3·1″)			
$\frac{5}{8}$	0·20	3 9	30·1	6·02	
,,	,,	6·5	31·9	6·38	
,,	,,	7·5	31·2	6·24	
		(on 2·5″)			
$\frac{1}{2}$	0·12	8·0	35·7	4·29	
,,	,,	7·2	35·3	4·24	
,,	,,	4·8	32·9	3·95	Stripped Thread.

In determining the pressure on the bolts, the steam pressure has been multiplied by the area of the bore of the pipe, and divided by the collective cross-sectional area of the bolts at the bottom of the thread. In Tables IX–XI the largest circumferential pitch of bolts is given as 4·51 inches, as in practice it is found that to avoid abnormal thickness of flanges this dimension should not be exceeded. In the case of cast-iron pipes, if a larger dimension were adopted and the thickness of flanges increased in a corresponding degree, internal strains are apt to be set up at the root of the flange when the metal is cooling. Various other conditions arise which affect the decision as to the pitch of bolts, similar to those met with in deciding the thickness of flanges, and makes the point difficult to settle by theoretical calculation, owing to strains to which the joint is sometimes subjected, by contraction and expansion when the steam is alternately admitted and shut off. The jointing ring too is often affected by water of condensation acting upon it, and particularly so when the material is asbestos. Again, in the case of plain flanges without recesses, trouble frequently occurs by the displacement of the jointing rings when the centres of the bolts exceed this dimension. The recognition of this limit of 4½ inches, therefore, and the observance of the principle of the multiple of four with respect to the assemblage of bolts, together determine the number of bolts to be used in the various flanges. Thus for pipes from ½ inch to 2½ inches inclusive, four bolts are adopted; for 3-inch to 7-inch pipes, eight bolts; for 12-inch to 16-inch pipes, sixteen bolts; for 17-inch to 20-inch pipes twenty bolts; and for 21-inch to 24-inch pipes, twenty-four bolts. The change from four to eight occurring as it does on 3-inch pipes necessarily makes the number of bolts more than is strictly required; but the only alternative is either to adopt a number not divisible by four, or to use only four bolts, which would make the circumferential pitch as much as 4·71 inches; and this dimension would bo altogether excessive for a flange when working at, say, 250 lbs. pressure. Assuming the adoption of eight bolts, it may be pointed out that the actual difference is not so great as it seems, inasmuch as if four were used, ⅝-inch or ¾-inch bolts would be necessary, but with eight probably those of ½ inch would be sufficient.

It may be explained at this point, that what has hitherto been said applies to cast-iron flanged pipes used for steam, to wrought iron or steel pipes with screwed flanges in cast-iron or steel, or brass and copper pipes with flanges of iron, or other metal, and to steel and wrought-iron pipes with flanges into which the pipe is expanded, or secured by rivets. No account has been taken of hydraulic pipes, which are usually secured with very heavy oval flanges.

For the purpose of comparing the proposed standard with those already in use, diagrams have been prepared, Plates 27 to 29, showing the differences in diameters of flanges, and in the number of bolts. It will be seen that the present proposals give flanges slightly in excess of those of the American low-pressure standard, but that in no case is the variation more than 1 inch in the outside diameter. The American standard adopts the principle of the multiple of four in arranging the bolt-holes, but four bolts are used for pipes from 2 inches to 4 inches inclusive, whereas in the proposed standard four bolts are not used for pipes larger than 2½ inches. In respect to pipes above 4 inches in diameter the two standards agree as to the number of bolts, except the 8-inch, 12-inch, 14-inch, and 18-inch pipes, in which cases the American low-pressure standard contains four bolts less in each flange. Turning to the high-pressure standard, it will be noted that the diameter of flanges in the present proposals are somewhat smaller than those of the American standard, varying from ¼ inch for 3-inch pipes to 2 inches on the 24-inch pipes. There is agreement in the two standards as to the number of bolt-holes up to and including the 5-inch size, and several above that size also agree. Generally speaking, however, the American high-pressure standard contains more bolts for pipes of 6 inches diameter and upwards; while for 14-inch pipes the American standard has twenty bolts of ⅞ inch diameter as against 16 bolts of 1 inch diameter in the proposed standard.

Turning to the German standards, difficulty arises in making an exact comparison, owing to the different systems of measurement; but generally it will be seen that in the German standard the flanges are somewhat smaller in diameter for a given size of pipe than those proposed in this Paper. The difference is, however, but slight, as reference to the diagrams, Plates 27 and 28, will show. For instance, a pipe of 150 mm. (or $5\frac{15}{16}$ inches) inside diameter has a flange 300 mm. (or $11\frac{13}{16}$ inches) diameter, whereas in the proposed standard the flange for a 6-inch pipe is 12 inches diameter. Unfortunately the sizes of the flanges in the two German standards do not agree, except for pipes up to 80 mm. (or $3\frac{5}{32}$ inches) inside diameter. As for example, the difference in the size of flange on a pipe of 400 mm. (or $15\frac{3}{4}$ inches) inside diameter is but 30 mm. (or $1\frac{3}{16}$ inch); and seeing that the amount of material saved by this small difference is so slight, it would appear that, all things considered, it would have been more economical to have made these two sizes agree. As to the number of bolt-holes, the German standard does not agree with the one now proposed, except in a few sizes of pipes for the high pressures, and the German low-pressure standard is not interchangeable with that for the high pressure. This doubtless saves a few bolts for the low-pressure work, but it is questionable whether so much economy is derived from it as would be obtained from increasing the number of bolts to make them uniform with the high-pressure standard. Comparing the proposed standard with those given as being representative of existing English practice, Plate 29, it will be seen that as regards the diameters of flanges but little alteration is suggested, the chief difference being in the number of bolts. So far as can be ascertained no firm has, up to the present, adopted the multiple of four as a fixed principle. The difficulty in the differing systems of measurement must of course be confronted if an effort is made to institute an international standard for flanges, owing to the present English system of measurement. But as already a close approximation is made, in many cases, to identity of measurement, it does not seem difficult to arrive at a working compromise, by disregarding the vulgar fractions as far as possible, in the English system, and by departing occasionally from the existing continental custom of even numbers in millimètres.

It is apparent from the foregoing that, with the continuous expansion of international trade, it is desirable that if possible a standard should be adopted which will be applicable at home and abroad. Recognising the various interests involved, and the many branches of engineering to which this subject is applicable, and considering the advantage of an interchange of ideas with other societies interested in the subject, it would seem essential that any arrangement to secure success should meet the approval of the principal engineering organizations interested.

CAST-IRON AND CAST-STEEL FLANGED FITTINGS.

The want of uniformity is equally felt when considering the principal dimensions of these fittings. What has already been said in this respect with regard to flanges will be found applicable also to this branch of the subject; for it is as important to have interchangeable dimensions for fittings as for flanges. At present it is the case that those made by one firm are not of use for replacing those of another firm, should such necessity arise; whilst in numerous other ways, needless to particularise, experience constantly reveals the loss and inconvenience from the existing diversity and confusion in the patterns commonly used. At the present time very few manufacturers keep large stocks from which supplies can be drawn, and it was ascertained while procuring information relative to existing practice in this country, that wherever a standard had been formulated it was of a purely arbitrary character, and no definite principle had been laid down; indeed, in some instances the same dimensions for bends and tees were adopted for 4-inch, 5-inch and even 6-inch fittings. Again, in constructing a fitting, while a minimum amount of metal should be used, it ought to be consistent with adequate strength, and with proper facility for inserting the bolts and making the joint. Further, it is a matter of common experience that trouble is often caused by the dimensions of bends and tees being too small to allow of easy fixing. In face of these existing disadvantages, therefore, it is but reasonable to urge that the problem should be viewed from considerations of general utility, as well as from the point of view that would first present itself to the manufacturer. An endeavour has been made by the following proposals to arrive at a definite uniformity with respect to these fittings, for which Table XII (page 329) contains a series of standard

(*Continued on page* 334.)

TABLE XII.

Proposed Standard.—Dimensions of Cast-iron and Cast-steel Fittings and Connections.

(*Plates* 37 *to* 39, *and Figs.* 72 *to* 93, *pages* 330 *to* 333.)

Inside Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	Number of Bolts.	A.	B.	C.	D.	E.
ins.	ins.	ins.		ins.	ins.	ins.	ins.	ins.
½	3½	2½	4	2⅝	6⅝	5¼	4	7⅞
¾	4	3	4	3	7½	6	4½	9
1	4½	3⅜	4	3⅜	8⅜	6⅜	5	10⅛
1¼	5	3¾	4	3¾	9¼	7½	5½	11¼
1½	5½	4¼	4	4⅛	10⅛	8¼	6	12⅜
2	6½	5	4	4⅞	11⅞	9¾	7	14⅝
2½	7	5½	4	5¼	13¼	10½	8	15¾
3	8	6	8	6	15	12	9	18
3½	8½	6¾	8	6⅜	15⅞	12¾	9½	19⅛
4	9	7⅜	8	6¾	16¾	13½	10	20¼
4½	10	8¼	8	7½	18½	15	11	22½
5	10½	8¾	8	7⅞	19⅜	15¾	11½	23⅝
6	12	10	8	9	22	18	13	27
7	13½	11½	8	10⅛	24⅝	20¼	14½	30⅜
8	14½	12½	12	10⅞	26⅜	21¾	15½	32⅝
9	16	14	12	12	29	24	17	36
10	17	14¾	12	12¾	30¾	25½	18	38¼
11	18½	16¼	12	13⅞	33⅜	27¾	19½	41⅝
12	19½	16¾	16	14⅝	35⅛	29¼	20½	43⅞
13	21	18¼	16	15¾	37¾	31½	22	46¼
14	22	19	16	16½	39½	33	23	49½
15	23	20	16	17¼	41¼	34½	24	51¾
16	24	21	16	18	44	36	26	54
17	25	22	20	18¾	45¾	37½	27	56¼
18	26	23	20	19½	47½	39	28	58½
20	28	25½	20	21	51	42	30	63
22	30	27½	24	22	54½	45	32	67½
24	32	29½	24	24	58	48	34	72

The dimension A = Diameter of Flange × 0·75.
" " B = A + D.
" " C = A × 2.
" " D = { Diam. of Flange + ½″ up to and including 2″ diam.
" " " + 1″ " " " " 15″ "
" " " + 2″ " " " " 24″ "
" " E = A × 3.

Do not drill bolt-holes on centre line, but symmetrically each side of it.

Proposed Standard Flanged Connections in Cast-iron and Cast-steel.

(For letter references see Table XII, page 329.)

FIG. 72.—*90° Bends.*

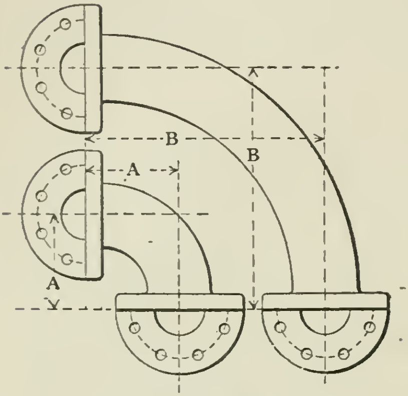


FIG. 73.—*45° Bend.*

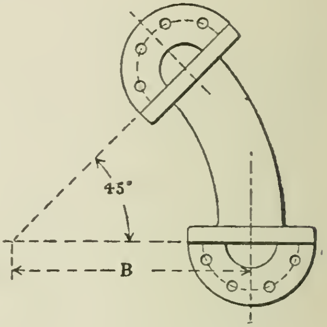
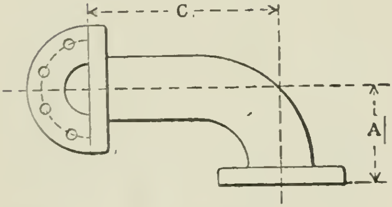


FIG. 74.—*Long Bend.*



8 holes.
3″ to 7″ pipe inclusive.

4 holes.
$\frac{1}{2}$″ to $2\frac{1}{2}$″ pipe inclusive.

FIG. 75.—*Swan-Neck Bend.*

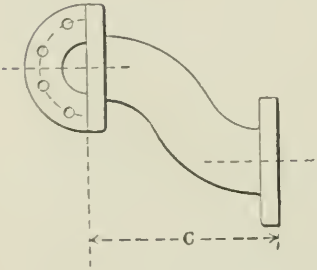
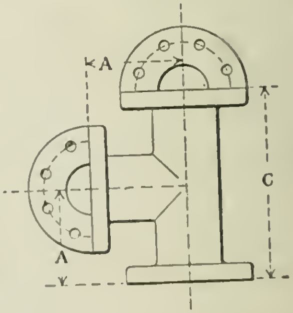


FIG. 76.—*Equal Tee.*



Proposed Standard Flanged Connections in Cast-iron and Cast-steel.
(For letter references see Table XII, page 329.)

FIG. 77.—*Branch Tee.*

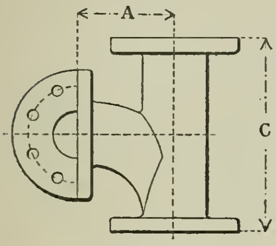


FIG. 78.—*Easy Tee.*

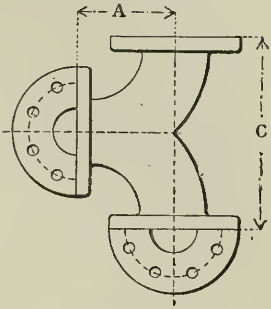


FIG. 79.
Tee with Reduced Centre Branch.

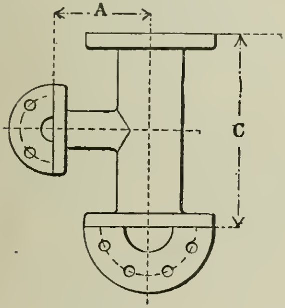


FIG. 80.
Tee with Reduced End Branches.

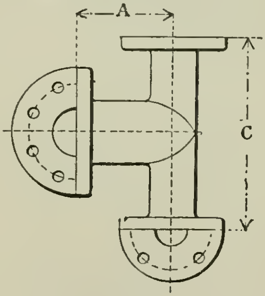


FIG. 81.
Tee with Reduced Centre and End Branch.

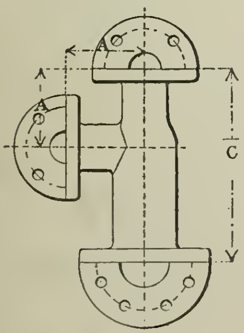
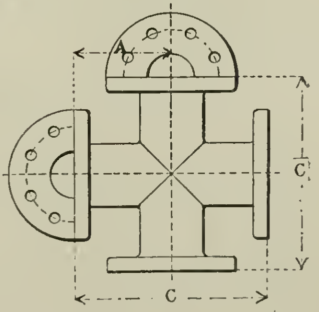


FIG. 82.
Equal Cross.



Proposed Standard Flanged Connections in Cast-iron and Cast-steel.
(For letter references see Table XII, page 329.)

FIG. 83.—*Close Syphon.*

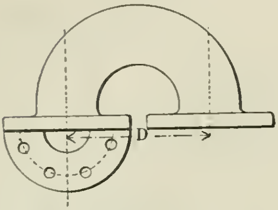


FIG. 84.—*Open Syphon.*

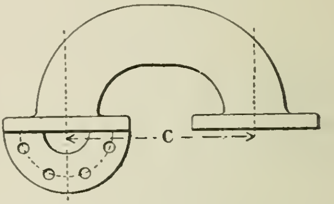


FIG. 85.—*Close Outlet Syphon.*

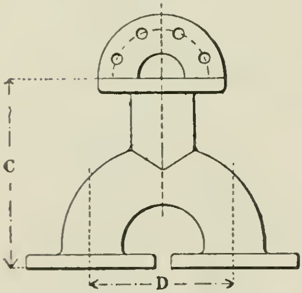


FIG. 86.—*Open Outlet Syphon.*

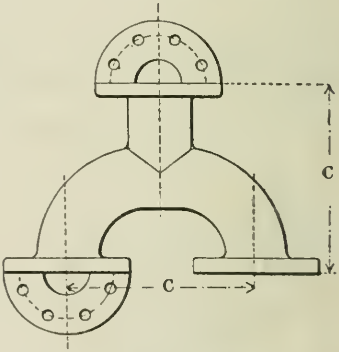


FIG. 87.—*Equal Junction Tee.*

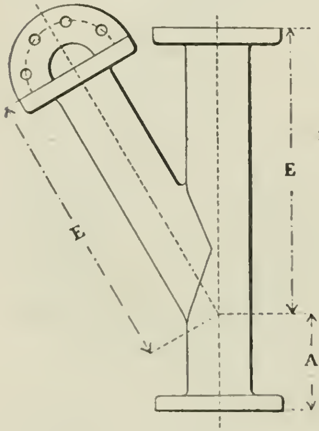
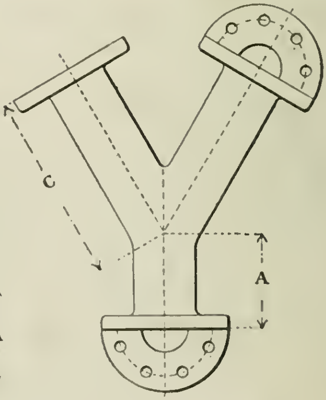


FIG. 88.—*Equal Y Connection.*



Proposed Standard Flanged Connections in Cast-iron and Cast-steel.
(For letter references see Table XII, page 329.)

Fig. 89.—*Reducing* Y *Connection.*

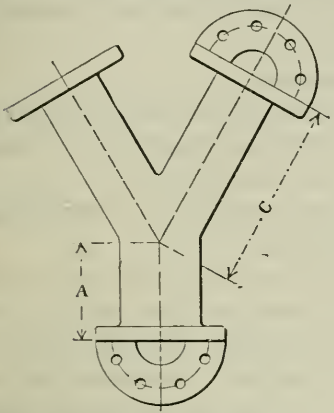


Fig. 90.—*Angle Pocket Connection.*

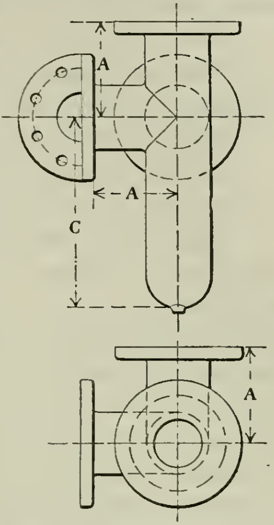


Fig. 91.—*Cross Pocket Connection.*

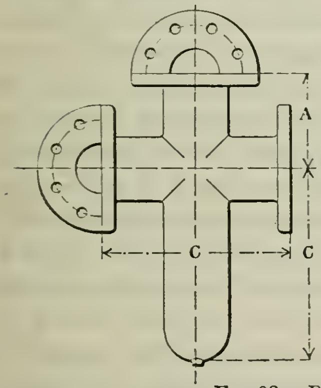


Fig. 92.—*Tee Pocket Connection.*

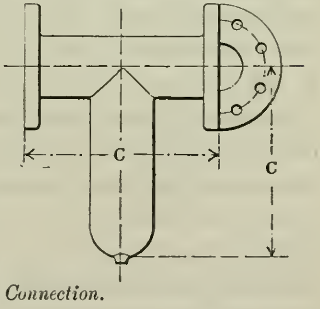
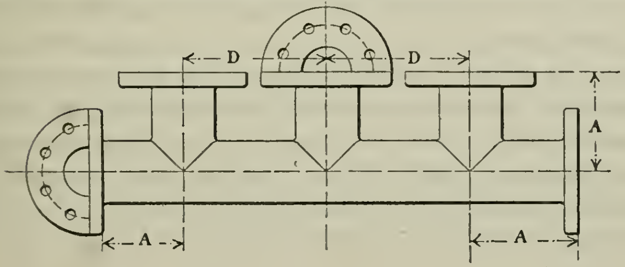


Fig. 93.—*Distributing Connection.*

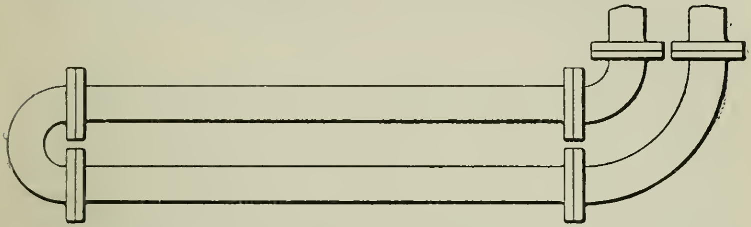


over-all dimensions, and Figs. 72 to 93 (pages 330–333) show drawings of the various kinds of fittings to which the proposals apply, these including the majority of patterns in common use. The guiding principles that have been observed are :—

1. A minimum number of dimensions.
2. Interchangeability of the various types of fitting for each size of pipe ; as, for instance, a bend should fit the position occupied by a tee, if required, and *vice versâ*.
3. That the over-all dimensions should bear a proportionate relation to the size of the flange.

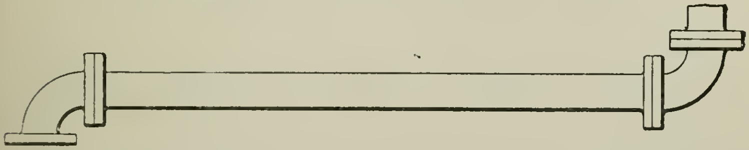
The sizes of flanges given in the Tables of the proposed standard are to be taken as applying to these fittings. Five dimensions are arranged in the proposed Table, to cover the various fittings of each size, and facility of calculation has been deemed to be one of the essentials. It was also thought desirable to so arrange these dimensions that they might bear some ratio to the inside diameter of the pipe ; but in working out detailed drawings of various sizes, while it was found convenient to adopt this rule for fittings up to 4 inches internal diameter, the larger sizes worked out unnecessarily large. The rule that has been adopted, therefore, is that dimension A on Figs. 72 to 93 (pages 330–333), and Plate 30, is the diameter of the standard flange multiplied by 0·75. The dimension C of the thoroughfare of the tee is made double this size, or the diameter of the standard flange multiplied by 1·5. Thus it will be seen that the advantage previously referred to as being highly desirable is obtained, and a bend could, when required, be used to replace a tee, or *vice versâ*. As to the necessity of the dimensions bearing a proportionate relation to the size of the flange, it is well to point out the convenience that must be afforded to the draughtsmen in setting out the work, to the machinist and to the erector, who in many cases may be working away from home. The rule now advocated has, moreover, the advantage of being easily committed to memory, and would, therefore, avoid the necessity of providing workmen and others with extensive tables of sizes. All that would be required in determining the size of any fitting would be the list of standard flanges and a slight arithmetical calculation. Dimension A is undoubtedly the principal one to be dealt with. The chief factor to be considered in determining it is the space required for the convenient insertion of the bolts in those holes which are placed near the inner radius of the bend. This becomes important when two bends are to be bolted together, and when a bend is connected with a valve, or other similar short-necked fitting. Dimension B is for a bend of large radius and outside the smaller one, and is suitable for arrangement of pipes as shown in Fig. 94, and also in Fig. 72 (page 330).

Fig. 94.—*Arrangement of large and small 90° Bends.*



The dimension B is arrived at by the addition of the dimensions A and D. Dimension C is obtained by multiplying A by 2, and is suitable for the long bend, Fig. 74 (page 330), for the thoroughfares of tees and crosses, and for the length of swan-neck bends and other fittings. In the latter case if the bend is required of very wide centres it may be formed by two standard bends with dimension A, Fig. 72 (page 330), joined with a piece of pipe, as shown in Fig. 95.

Fig. 95.—*Wide centre bend formed by two small 90° Bends.*



Dimension D is determined by adding to the diameter of the standard flange a certain clearance between the two flanges, in order to facilitate access to the bolts, and this space is arranged to be ½ inch for syphons up to 2 inches inside diameter, 1 inch for syphons 2½ inches to 15 inches inside diameter, and 2 inches for syphons 16 inches to 24 inches inside diameter. This space is useful if it is required to machine the edges of the flanges, and would make provision for the accommodation of the bodies of globe valves. Dimension E is A × 3, and is necessary for junction fittings, Fig. 87 (page 332). In designing reducing tees, dimension A must be calculated on the basis of the largest branch, as it frequently happens that the centre branch of a tee is required larger than its thoroughfare, and were this dimension not based on the larger branch it would prevent the possibility of inserting the bolts in the flanges of the thoroughfare. Thus a tee made as Fig. 80 (page 331) with a 6-inch centre and 4-inch thoroughfare would be calculated as follows:—

6-inch standard flange equals 12 inches in diameter, and 12 by 0·75 equals 9 inches, which is dimension A. Dimension C equals A × 2, equals 18 inches, which is the length of the over-all branch of the tee. The same method of calculation would apply to all reducing tees and crosses under all circumstances, and would also be the means of determining the length of the branches for the outlet syphons, Figs. 85 and 86 (page 332).

It may be interesting to note that the American Journal "Power" published as monthly supplements, from December 1897 to November 1898, a series of valuable Tables, giving the dimensions and weights of cast-iron flanged fittings, as made by the four principal firms manufacturing them in America. These publications brought out the fact that the goods were not interchangeable; at the same time there did not appear to be any valid reason why this desirability was not secured.

It has not been considered necessary to illustrate the whole of these various standards, but it may be said that the dimension heretofore spoken of as A did not vary for a 6-inch fitting more than 3 inches in the four standards. One of these standards is given, however, on Table XIII (page 337), that of the Crane Company of Chicago, and on Fig. 7, Plate 30, is a diagram comparing this standard with the one now proposed. From this it will be observed that the Crane Company's standard and the one now proposed do not largely differ, while the merit of the latter lies in the fact of its being correlative to the diameter of the flange.

TABLE XIII.

Dimensions of Cast-iron Flanged Fittings and Connections, as used by Crane Company, Chicago.

(*See Plate* 30.)

Inside Diameter of Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	Number of Bolts.	A.	B.	C.	D.
ins.	ins.	ins.		ins.	ins.	ins.	ins.
2	6	4¾	4	4½	2⅝	9	—
2½	7	5½	4	5	$2\frac{15}{16}$	10	5
3	7½	6	4	5½	$3\frac{3}{16}$	11	5¼
3½	8½	6¾	4	6	3½	12	5½
4	9	7¼	8	6½	3¾	13	5⅞
4½	9¼	7¾	8	7	$3\frac{13}{16}$	14	6⅛
5	10	8¼	8	7½	$4\frac{1}{16}$	15	$6\frac{7}{16}$
6	11	9¼	8	8	4⅝	16	7
7	12½	11	12	8½	5½	17	7½
8	13½	12	12	9½	5⅝	19	$8\frac{1}{16}$
9	15	13	12	10¾	$5\frac{11}{16}$	21½	8⅝
10	16	14¼	12	11½	$5\frac{15}{16}$	23	9⅛
12	19	17	16	12¾	6⅛	25½	10¼
14	21	18½	16	13¼	$7\frac{9}{16}$	26½	11⅜
16	23½	21½	20	15¼	$8\frac{1}{16}$	30½	$12\frac{7}{16}$
18	25	22½	20	16½	8⅛	33	13½
20	27½	24¾	20	18	9⅜	36	$14\frac{9}{16}$
22	29½	27½	24	20	10½	40	$15\frac{11}{16}$
24	31½	29½	24	22	11½	44	16¾

The dimension D is for a 2½" Branch, and will vary according to the diameter of Branch. Flanges are drilled in multiples of four, so that fittings may be made to face in any quarter, and holes straddle centre line.

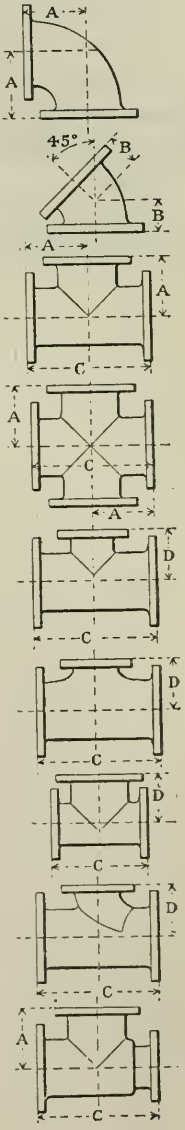


Fig. 8, Plate 30, gives a diagram of comparison between the present practice of two representative British firms and the one now proposed. As before mentioned, the standards of the two firms do not appear to have been designed on a definite rule or principle, and, on the whole, exceed the dimensions actually required. In dealing with these fittings, as with the standard flanges, the question of thickness of their bodies and strength of flanges has been discarded; but it is believed that the over-all dimensions suggested are amply sufficient to cover the requirements of pressures up to 250 lbs.

The Paper is illustrated by Plates 27 to 39 and 27 Figs. in letterpress, and is accompanied by 13 Tables and 1 Appendix.

APPENDIX.

Being portion of a communication sent to the Institution by Messrs. Lloyd and Lloyd, Albion Tube Works, Birmingham.

Messrs. Lloyd and Lloyd recently wrote to upwards of twenty manufacturing private firms, or companies, in England, whom they considered to some extent representative of the trades interested in the subject of the Standardization of Flanges. While they could not say that the list was as complete as possible, yet it was sufficient to prove that the Engineers and Manufacturers in Great Britain would welcome an attempt to standardize Flanges.

Sixteen replies were received as follows :—

Query.	Reply.		
1.—Are you of opinion that a standard or standards for flanges should be fixed by the engineers and manufacturers in Great Britain?	Yes. 16		No. 0
2.—Should there be one standard for all pressures up to 200 lbs. steam per square inch?	Yes. 1		No. 14
3.—If you do not approve of one standard only, how many would you suggest for meeting all requirements, ranging from low-pressure gas and water, to high-pressure steam?	No. of Standards. Two. 6		Three. 8
4.—If not similar in details, should the diameter of the flanges be the same for all pressures?	Yes. 8		No. 5
5.—Do you consider it necessary to standardize thicknesses of flanges in addition to the diameters and bolt circles?	Yes. 7	No. 4	Perhaps. 2
6.—Should the number of bolt holes in all cases be multiples of 4? . . .	Yes. 4		No. 9
7.—Would you agree to recognize and to adopt *as far as possible* the standard or standards decided upon by the majority?	Yes. 15		No. —

Discussion.

The President thought there could be no two opinions either as to the importance of the subject which had been dealt with by Mr. Atkinson in the Paper, or as to the ability with which he had collated and arranged the data he had put forward. The main facts had been placed before the Institution in a way that would enable them to be efficiently discussed, and he asked the members to return to the author a hearty vote of thanks for the trouble he had taken.

The resolution was carried with acclamation.

The President said the Paper differed very materially from many of the communications which had been brought before the Institution. It was desirable that it should have a result more or less definite: that the Paper should not be merely discussed, and the opinions of members stated upon the various points raised, but that, after such discussion, some standard should be arrived at which the Institution could recommend for adoption by the various makers and users of pipes and fittings. The Council had had the question before them that afternoon, and it had been decided that the best way to secure that very desirable end would be to treat the matter as follows:—It was proposed to take the discussion on the Paper that evening as far as time would allow, and then to circulate the Paper with the report of the discussion, as far as it had gone, to all persons likely to be interested in this particular matter, both in this country and abroad. All those to whom the communications were so sent would be invited to transmit in writing to the Secretary their criticisms of the points raised, and also to make any suggestions which would aid the Institution in arriving at a suitable standard or standards. All communications thus received, instead of being printed in the ordinary way, would be put into the hands of a small Committee which had been appointed that afternoon (and of which the author of the Paper was a member), so that they might be digested, and the suggestions they contained be put into order and arranged in such a way that they could be readily compared. The summary of the communications thus obtained would be submitted at one of the first Autumn meetings of the Institution as a Supplementary Paper, and the discussion would then be continued. He thought in that way far more good would be done than could possibly be secured by merely adjourning the discussion for a week, and then taking it up in the ordinary way. The Paper, to be discussed properly, needed to be read very carefully and to receive a very large amount of consideration. He hoped the course suggested would commend itself to the members; he assured them that the Council had considered the matter very carefully, and had arrived at the conclusion that by dealing with it in the manner he had described, results would be secured which would be of much advantage to the profession.

Mr. ATKINSON, in response to the President's invitation, after acknowledging the favourable reception accorded to his Paper, pointed out that the question of standardizing flanges differed from the standardization of machine parts. A large proportion of the work done in connection with flanged joints was executed at a distance from the works at which they were produced; while machine parts were chiefly dealt with in the factory, and made to a limit gauge. This fact of the large amount of labour entailed at a distance from the factory added greatly to the importance of any considerations that might be advanced, with the object of economising or restricting that labour to the minimum essentials. Speaking as a contractor, he considered that it would be much cheaper to spend a few extra shillings in having them right from the fitter's standpoint, than to send out goods which had been produced more exclusively from the point of view of the manufacturers' immediate interest. The question of the number of bolt-holes was very important, and especially so in respect to the fittings. To have 6, 9 and 10 holes, or any number not a multiple of 4, also added greatly to the difficulty of stocking these fittings.

Standards must be always more or less of a compromise, especially when large ranges of subjects had to be considered, such as that of locomotive or marine work, power and electric plants, etc. In

(Mr. Atkinson.)

formulating an international standard a certain difficulty would be met with on account of the differing systems of measurement. In this country engineers kept to the 12 inches, and 12 inches expressed in millimètres meant an odd number; while continental firms, in determining the dimensions of flanges, preferred 50 and 100, and certainly not less a division of the hundred than 25, for the diameter. But the desire of an international movement for unification was so apparent that he appealed for a spirit of mutual concession, and believed that, in that spirit, all difficulties could eventually be overcome.

Mr. C. E. STROMEYER welcomed the spirit which had prompted the production of the Paper. The Institution of Civil Engineers were standardizing bar sections, and this Institution had, as it were, tried to standardize materials. He was almost inclined to suggest that they should wait and learn more about materials before going into the question of standardizing dimensions, because, if some materials should be discovered which were better than what were used now, the standards might have to be altered. But they might have to wait too long, and it was far better to do something in the direction indicated at once. The question of standardization had been mentioned at the Dinner on the previous evening (page 301), and engineers were blamed for not standardizing their locomotives. That at least was said to be part of the reason why locomotives had to be bought in America; but he believed a far more potent reason was the fact that the Indian Government had been trying to save money for a long time; and then suddenly, when busy times came along, orders were given with great rapidity, just at the time when England was very full of work. He hoped that that point would not be overlooked, and that the standardization of locomotives, which must necessarily be a very difficult work, would not be carried too far. Standardization simply meant crystallizing practice, from which in future days it might be perhaps very difficult to escape. For instance, this country was the first, as far as he knew, to standardize the threads of screws. The Whitworth standard was recognised largely, but even nowadays that standard was not universally adopted, and was being departed from more and more. In boilers it had been practically never adopted, as boiler-makers always preferred finer threads than the Whitworth standard. In small screws also the standard was different. A departure was thus seen to be taking place in one system of standards which seemed at one time to be carrying everything before it.

In making some remarks which might be considered adverse to the Paper, he did not in any way wish to give the impression that he considered pipe flanges should not be standardized; but there were various points which had to be taken into consideration, especially as the whole matter would be laid, as it were, before the engineering world. One question he desired to ask was, what clearance was going to be allowed in the bolt-holes? If the flanges were to have all the holes drilled at the works, they would have to be very accurately drilled to fit other flanges. It necessitated very perfect gauges, and he was afraid the older pipes would not have been drilled in that way, and rimering or drilling would have to be resorted to. That looked to him as if the holes would have to be made considerably larger than they would have to be made if they were drilled in place. Two considerations had to be observed in the standardizing of pipes. In designing a pipe and flange of any particular metal, either brass, cast-iron, or steel, the natural tendency at first would be to have as many bolts as possible, and keep the pitch circle as small as possible. That tendency would be due to considerations of strength, because the farther away the bolts were from the pipe, the more tendency there would be to strain its metal. He wished to draw attention to the Board of Trade Report No. 1212, in which a case was shown of a cap breaking due to the jointing material being placed inside the bolt rings, and the pressure of the bolts broke the material of the cap close to the flange. He mentioned this particular case rather than others of broken pipes, because the breakages might be due to the bending of the pipe or to vibration. Another case was No. 1175, in which some jointing material was blown out, because it had deteriorated, showing that the jointing material should be made as thin as possible. In fact, it was the Manchester Steam Users' practice to suggest faced joints with only a little red paint. Formerly

(Mr. C. E. Stromeyer.)

they used to specify spigots, but that had been given up, as it was found that the simple red paint between the joint made about as good a joint as could be possibly obtained, and seemed to last very well. These remarks of his tended towards making the flanges as small as possible, keeping the bolts as near to the pipes as possible, and making more numerous and smaller bolts; but from a commercial point of view, and from the point of view which he thought the Committee might feel inclined to take, the flanges should be made as large as possible, so large in fact that they would cover all the standards which had been adopted anywhere else. He was assuming that the question of drilling the holes before the fittings left the shops might perhaps not be pressed forward, as much as it was done in the Paper. With flanges of the very largest diameter, the fittings or pipes might be sent out with the assurance that they would fit any pipe to which they had to be attached; and supposing there was a breakdown anywhere with German, American or French pipes, it would be possible to be sure that the flanges would always cover, whereas if the flanges were too small, and possibly the pitch line of the bolts too large, the holes might have to be cut through the outside of the flange, which would be very annoying.

The author had regulated the pitch of the bolts by the outside diameter of the flanges, and Mr. Stromeyer did not quite agree with that. He thought that even if the inner diameter of the pipe was not quite the ruling factor, certainly the pitch line might be taken more into consideration, because although he recommended jointing the whole surface, many people only put the jointing material in the centre, especially if there were spigots in the flanges. Also if the size of bolts was to be standardized, he thought the area of the flanges rather than the sectional area of the pipe ought to be taken into consideration, because a very wide flange required a very much heavier pressure on the jointing material to keep it tight than did a narrow one; in fact some engineers preferred to have flanges which were exceedingly narrow, and, as he had already mentioned, with very small and numerous bolts and a very narrow jointing ring great success was obtained in keeping the pipes tight. But if the very largest flanges should be adopted, the width of flanges would have to be taken into account, and the size of bolts determined accordingly. It would not do simply to take the steam pressure into account, but the pressure necessary to secure an absolutely good joint. As a marine engineer he could say there was as much trouble with copper pipe-joints as with any others. The difficulty with them was the brazing of the copper pipes to the gun-metal flange, and there was also the danger of the gun-metal flange being bent. In fact he believed there was hardly any copper steam-pipe which went into a steamship, in which the gun-metal flanges had not been bent during the hydraulic test. It was an almost invariable practice to have to file over their surfaces, before putting them into the ship.

He wished to go back to the question of bolt-holes, and the difficulty attending their being drilled in the works. The breakdowns of steam pipes were not very frequent; he believed during the last seventeen years there had been only fifty explosions of steam pipes on land-boilers, what might be called real explosions, not only the blowing out of the joints, but the fracture of pipes. Even when a pipe did explode, it was of no use wishing to replace it at once, for it had generally to be left in position until the Board of Trade had made their report; and he doubted if anyone would wish to go on working straight off, after there had been a serious explosion. Therefore there was usually enough time to get a new pipe, and there ought to be enough time to drill the holes in position or to templets. He feared nobody would care to stock pipes on the off-chance of being called upon to supply them at once. Not only was the length not known, but even if the length were also to be standardized, there would be always the difficulty of knowing how the holes fitted on the two ends of the flange. If, say, eight holes were drilled into the one flange and eight holes into the other, it was even then not certain that those two flanges in the pipe arrangement were absolutely at the same angle from a torsional point of view, and that would mean chipping or filing out the holes, which would be more troublesome than having to drill the holes in position. He also mentioned that those who asked him to draw up boilers for them were usually very proud of their boilers, as proud

(Mr. C. E. Stromeyer.)

as any railway company was of their locomotives, and they liked to use turned bolts with polished nuts and turned flanges for the boiler fittings. He did not know how far such details would affect standardization, whether polished flanges might be allowed to be made smaller than the rough ones, in order not to go to any extra expense with the patterns. He mentioned an experience which he underwent not very long ago, which showed how people were very particular in regard to their boilers. A complaint reached him that the rivets in the circumferential seams were not equally pitched; when he looked into the matter he found that the irregularity occurred where the circumferential seam crossed over the longitudinal, and naturally the pitch would be there slightly altered. The defect was but slight, but the attention paid to it showed how very particular some men were sometimes in such details, and it also showed that they took a great pride in their boilers.

Another argument against the standardization of the holes was that, even though it might be cheaper to drill the holes in the shop, he did not think the question of saving thereby effected should influence the fitting of costly boiler additions, such as stop valves, because the chief expense of a valve should be in the valve itself. The gun-metal should be first class, and the screws and the cover and the whole of the valve ought to be so costly, in comparison with the holes that were to be drilled in the flange, that it should not matter whether those holes were drilled in the shop or in place. He really could not conceive why, if a stop valve was fitted on a boiler, anyone should wish to turn it round through an angle of 90°. He knew a few cases where superheaters had been fitted to boilers after the boilers had been at work, but supposing there were six or even fourteen holes in the flange, it would not be a very difficult matter to arrange the pipes so that they would fit in. The pipes would have to be special castings in any case, and if the valve had to be turned it could be turned through almost any angle. He hoped that point would be taken into consideration when the matter went further.

Mr. David M. Nesbit considered the standardization of flanges to be a very urgent question. He stated that he had studied the matter for a number of years both by himself and in conjunction with the author, and had felt the necessity for something being done. While he agreed with a great deal that Mr. Stromeyer had said, he could not agree with some of that gentleman's ideas. From a commercial point of view, it was very necessary to have some standardization whereby the stock of the manufacturer might be made of greater utility than was generally the case. He was quite sure that any member who had studied this point as seriously as he had done for the last fifteen or twenty years would say that the stock question was a most important one. He would have liked to hear some remarks from Mr. Hopkinson of Huddersfield, a gentleman whose name he had known for many years, and he was quite sure Mr. Hopkinson could give some very valuable data. The question of six holes, as Mr. Stromeyer had pointed out, was one that could not be defended, for whatever advantage there might be it was far outweighed by the disadvantage of not having the number of holes divisible by four. For instance, if an engineer had fixed a 6-inch stop valve on a boiler, and for some reason or other this valve had to be removed and placed in stock, it might be found difficult to use the particular valve again, as the position of the holes might be quite different in the second instance to the first. The result would be that the original valve would have to be returned to stock, and such cases might prove a serious loss in course of time to engineers if not to manufacturers of the valves. The manufacturer would find he had considerable dead weight to carry, when stocktaking came round. The commercial value of the standardization of flanges was a matter which appeared to him to be of the greatest importance, not only to the engineering industries of this country, but also to those of France, Belgium, Germany, and America; and he hoped the Committee which had been appointed that afternoon would bring about results that would have far-reaching effects, inasmuch as they would endeavour to make standards not only for Great Britain and Ireland, but also to come into line with America and Europe. He felt very strongly about this because, although his

(Mr. David M. Nesbit.)

business was only a small one, the loss entailed by having to carry stock of various kinds was a very serious one. Only a few days ago he happened to go through one of the yards of his works at Leicester, where he found pipes which had been lying there for a number of years, which could not be cleared out of the way.

So far as jointing material was concerned, a good deal that Mr. Stromeyer had said he agreed with, but if a jointing material was used that would cover the whole of the flange, he did not see any difficulty in making a good joint, whether it was for 5 lbs., 50 lbs., or 200 lbs. pressure. With regard to the holes coming into line, which Mr. Stromeyer pointed out might form a difficulty, that might be easily overcome, as the number of bolt-holes and bolts increased in the flanges so the strength of the joint increased in the same proportion. He did not wish it to be understood he favoured the idea that the metal was not weakened by making more holes in the flanges, on the contrary, it helped to weaken the flange, but at the same time that weakness was compensated for by the extra number of bolts, probably not only by the number of bolts that were put through the flanges, but there was also compensation in the increase of the diameters of the bolts themselves. He had a case not many weeks ago where $\frac{3}{4}$-inch bolts were put in some pipes which had to be taken out, and replaced by $\frac{7}{8}$-inch bolts. Since the $\frac{7}{8}$-inch bolts had been put in, the joints had remained perfectly tight. He only gave that illustration to show that it was possible, by increasing the diameter of the bolt, to make a substantial joint. This was his experience, and he believed the experience of many engineers in the branch of engineering which he followed. He hoped the members of the Institution would support the Committee in bringing about some standard, whether it was the standard proposed in the present Paper or another; it did not matter so long as a standard was adopted whereby it became possible to prevent waste of time, waste of material, and waste of energy which served no good purpose, and which ended only in turning good materials into scrap.

Mr. Walter B. Incledon referred to the Appendix (page 339) at the end of the Paper from the firm of Lloyd and Lloyd with which he was connected, and said that when Messrs. Lloyd and Lloyd took the matter up a short time ago they were not aware that a Paper was to be read on the subject; consequently they had rather hesitated to go on with it, and whatever information they possessed they put at the disposal of the Institution. He wished to say a few words on the commercial aspect of the question, which had been already touched on to some extent. What had struck him first of all upon reading the Paper was the mass of information which had been collected by the author on the practice of other firms in the diameters and drilling of flanges. Considering the mass of information which the author thus had at his disposal, he confessed to a feeling of disappointment when he found, on comparing the standard which the author suggested as a suitable standard for adoption, that that standard was not built up on the information and practice of other firms, but was simply the standard which the author's own firm had been using for the last three or four years. It seemed as if the information he had been collecting was somewhat wasted, and he thought it would have been better if the author had used all the information to compose a revised standard, rather than suggest the adoption of the standard of one firm. If the question was approached with the view of adopting any one firm's standard nothing would result; it was the accumulated information and experience of all the firms which would in the end produce a satisfactory standard. He thought it was hopeless at the present moment to expect to form an international standard, as the standard of measurement was quite different on the Continent. At any rate, it was not within the range of practical politics at the present moment. Possibly something might be done with America. With regard to the number of standards, it was suggested by the author that one standard diameter of flange and one standard diameter of bolt circle should be made. From a commercial point of view that would be a great disadvantage. In the author's example of a 3-inch flange, there was a diversity of practice with regard to the diameter ranging from 6¾ to 8¾ inches. The diameter which the author recommended was 8 inches, but there was no doubt that 7 inches was an ample diameter for a 3-inch flange for low-pressure work. By increasing that diameter to 8 inches, the weight

(Mr. Walter B. Incledon.)

of the flange was increased 30 per cent.—a most serious matter in gun-metal, and a more or less serious matter in iron. It was a very serious matter to tube manufacturers, who occasionally had to supply long lines of a good many thousand feet of flanged tube. Multiplying the extra cost on each pair of flanges by the number of lengths of tube, a very serious addition was made to the initial cost of manufacture; and as a great deal of extreme competition had now to be met with in foreign and American manufacturers, the initial cost of manufacture had to be carefully considered. Again, the author increased the cost of manufacture, particularly of the 3-inch size, by multiplying the number of bolt-holes which entailed extra drilling and increased the number of bolts. Even if the bolts were rather smaller, when using eight instead of four, the extra cost was a consideration, and must be considered in dealing with the question of standardization of flanges. He quite agreed with the author that there need be no difficulty about arranging that all bolt-holes should, as the Americans say, straddle the vertical axis; but with regard to the question of the multiples of four he was not so much in agreement with him, and he found from the experience of other firms there were very few who had adopted the principle, as the author himself admitted. The author seemed to think there were none, but the speaker had tables in his possession which showed there were one or two firms who had adopted the principle of multiples of four, and he presumed successfully. The author's own firm was one example. There was no doubt that for low-pressure work, if it were necessary to use either eight bolts or six, the extra cost of putting in eight bolts instead of six was something which had to be considered. The practice of other firms seemed to show that it was not generally approved, or, at any rate, not generally carried out. It seemed to him that a possible solution of the difficulty would be to arrange a standard based on multiples of four for high-pressure and high-class work, and those engineering firms who wished to maintain a high-class standard for all their manufactures could adopt the high-class standard of the large diameter of flange with bolt-holes multiples of four; but he thought other standards should be allowed for low-pressure work, in which the question of multiples of two should be carefully considered by a Committee, and something done towards agreeing to a standard based on those lines. There was no doubt that if an agreement could be made as to two or three or even more standards, there would not be the immense amount of difference that at present existed, and it would be a great convenience, even if it were not possible to have one diameter of flange and one diameter of bolt circle for all pressures.

Mr. W. T. Hatch said he had come that evening with some trepidation, as the Paper was written by a manufacturer whilst he represented a large consumer, and consequently the author and himself approached standardization from different standpoints. The author spoke from a manufacturer's point of view, but even manufacturers apparently differed as to the advisability of following out all the suggestions made. As a private consumer he wished to make a few remarks. First of all, those in charge of large stations did not mind whether the fittings in use at their station were applicable to all conditions outside their own practice. If the station were run at 150 lbs. pressure, all that they required were reproductions suitable for that pressure, or if for a lower pressure they wanted them for that lower pressure. It did not matter to them whether the valve or pipe they were buying was suitable for a dozen different purposes or not; they wanted it to suit the identical one under their own charge. There was also the suggestion that it would be a great convenience for high-pressure fittings to be capable of being applied to low-pressure pipes, if the flanges were interchangeable. He had charge of a considerable number of engineers, men who were all good engineers, yet they were liable to make mistakes; and with the interchangeability of high-pressure fittings to low-pressure pipes, engineers in charge might be led to use low-pressure fittings in connection with high-pressure pipes, and a system which would countenance that would be bought at a very dear price. Accidents should be prevented by every possible means, but by adopting a system to embrace everything, something was lost in the universality which it gave. Thus there was the question of the increase in the size of the flange. Flanges were a very important

(Mr. W. T. Hatch.)

feature, and, as the representative of Messrs. Lloyd and Lloyd had just stated, long lengths of pipes had to be supplied with a large number of flanges. In the Institutions under the Metropolitan Asylums Board (which possessed over twenty), some housing 2,500 inmates, composing little towns of themselves, and having their own gas-works (or electric-lighting plant), deep well pumps, laundry plant, etc., a great variety of pipe work and fittings was experienced. In one hospital alone the main steam-pipe (consisting of 3-inch pipes and over) was three-quarters of a mile in length, and contained a great number of flanges. If the system suggested by the author were adopted, his Board would have to pay a great deal more for those pipes than they had hitherto done. There were about 440 lengths in the above-mentioned pipes and about 40 fittings, and he asked whether the latter were to be sacrificed for the benefit of standardizing the 440 lengths of piping. In Table VIII (page 315) the author gave a list of the standard flanges proposed by Messrs. Schäffer and Budenberg to the Society of German Engineers, but not approved by them. If he had been sitting on that Council, he would certainly have agreed with the German friends in that decision, for, as an instance of the value of the standard submitted, there was one pipe (half-way down Table VIII) the diameter being given as $4\frac{13}{16}$ inches, suitable for 176·4 lbs., and yet there were only 4-inch bolts provided, having a pitch of $6\frac{1}{2}$ inches. The author in his Paper recommended that the pitch should never exceed $4\frac{1}{2}$ inches, so that an eminent firm was suggesting an arrangement whereby the pitch should be $6\frac{1}{2}$ inches. He quite agreed with the Germans that the scheme should not allow of such a large pitch as that. The author did not say whether he agreed with the suggestion of Messrs. Schäffer and Budenberg, but as in all the other British cases tabulated he had commented favourably upon, the speaker presumed the author did agree with Messrs. Schäffer and Budenberg's suggestion. Tables were also given of the practice of Messrs. Hopkinson, and Mather and Platt, who provided for eight $\frac{3}{4}$-inch bolts, and Messrs. Dewrance used six $\frac{3}{4}$-inch for a 5-inch pipe, practically similar to the $4\frac{13}{16}$-inch pipe under notice. He thought the English practice would appeal to all engineers who had to do with public work, as being the more satisfactory of the two.

In Tables IX, X, and XI (pages 317–319) there was a suggestion that the standards should range from 0 to 50 lbs., from 51 to 150 lbs., and 151 to 250 lbs. steam pressure. The author had suggested in the case of hospitals that it would be very disastrous if they could not get replacements, and he quite agreed with him. But, although in some hospitals there was low-pressure heating below 50 lbs., in almost every hospital the same boilers used to provide steam for heating purposes worked at very much higher pressures, as they had to supply steam for pumping engines, electric lighting engines, laundry engines, etc. The 50 lbs. limit of standard would therefore be of little use, as it would necessitate having two sets of pipes, one for low pressure and one for high pressure. It was a common practice among some firms to arrange for the first standard to reach to 120 lbs., and the second from 120 lbs. to 250 lbs. The first grade up to 120 lbs. covered the large majority of cases of comparatively low pressure, so that one stock would be quite sufficient for ordinary practice; it would also allow for a standard of cast-iron pipes and fittings being used for pressures up to 120 lbs. He thought he was right in saying that the tendency now was that for pressures of over that amount pipes and fittings were made in wrought or cast steel, so that one standard could be adopted for cast-iron work and another for steel work. The question of uniformity of outside diameter flanges had been already commented upon, but in the case he had mentioned, where there were three-quarters of a mile of steam mains, the addition to the initial cost would be excessive. The author said that although the flanges were extra large, yet the only increase would be in the diameter, but he thought engineers as a rule, if they increased the diameter of their flanges, would want also to increase the thickness, so that there was extra expense not only in the diameter but in the thickness, and the consequent extra work in machining the extra diameter.

He hoped his remarks would not be taken to mean that he did not agree to any standard at all. He was heartily in sympathy with the author that some standard should be agreed upon, and was only giving his experience from a consumer's point of view. If the rule

(Mr. W. T. Hatch.)

the author had laid down with regard to uniformity of bolt-holes and bolt circles might be varied by adding the words "for certain specified conditions," he thought it would be an improvement. Then if anything were required up to say 120 lbs., there would be a fixed diameter and a fixed number of bolt-holes and fixed pitch circles. In advocating any new system of standardization, it would be very difficult to complete it without embodying the wishes of both consumer and manufacturer. There were probably ten consumers to every manufacturer, and the former should receive consideration, but any system that entailed extra expense would be received with very great reluctance.

With regard to the bolt-holes, Mr. Stromeyer had spoken of the question of drilling (page 345). Care would have to be taken in drilling the templates, and even when flanges were marked off and drilled by a multiple drill, the tendency for the drills to run was well known to engineers. A deadlock would be come to if two firms, one with a good drilling plant and another without, had their holes varying in pitch and also in size; therefore the question of clearance was one of very great importance. It was suggested in all cases that the number of bolts should be divisible by four, and from Table IX (page 317) it was apparently capable of being followed without undue discrepancy in regard to stress on the bolts in pipes of 8 inches and over. But in smaller sizes—and he thought these constituted the larger portion in ordinary practice—difficulty would be experienced in the sizes necessitating a sudden increase of from four to eight bolts, and any system which did really not apply to the majority of cases should be regarded with suspicion. The extra cost of drilling and cost of material and labour in turning the extra large flanges advocated by the author for low pressures, and the extra cost of the bolts in the long lengths would amount to a very large item, and increase perhaps the cost by 25 per cent. With regard to the fittings and the suggested necessity of being able to move them through a right angle, he did not think that was a very great point. He knew that in the fitting of globe valves on small fittings many engineers liked to have them horizontal, because the pipes drained better. That only applied to small valves, and engineers as a rule did not fix globe but rather "fullway' valves on large pipes. Four bolts for pipes up to 2½ inches in diameter he thought was ample for almost any conditions which might be laid down, but the numbers used in larger sizes should be multiples of two.

The author stated (page 321) "the difficulty follows that all valves and fittings must be kept in stock undrilled, causing extra labour and expense in handling again in the works when the position of the work is definitely decided." Speaking from his own experience he thought that the bolt-holes of four-fifths of the valves in use, or the fittings, or the pipes, were in a fixed position. When the holes were drilled, as had been suggested, on each side of the centre line, it probably met four-fifths of the cases; the other one-fifth being in the minority, it meant that the manufacturer had to keep one-fifth of his valves in stock undrilled, and in any case he would have to make provision for cases outside the ordinary standard, for a certain proportion of every-day work would be "special." It was impossible to work slavishly to standards.

With regard to the later portions of the Paper on the bends and tees, he thought too much praise could not be given to the author for bringing the matter forward, and if that portion alone had constituted the Paper, the thanks of engineers in general, and especially of the Institution, would be heartily accorded to the author; in fact the speaker wished most cordially to endorse the President's remarks as to the value of such an exhaustive contribution as that under discussion.

Mr. John Dewrance thought the view laid before the meeting by Mr. Hatch really touched the crux of the whole matter. It was all very well to lay down a standard, but it was quite a different matter to get users to adopt it. In many cases it was almost impossible to expect they would adopt it at once, because they had already standards of their own, and to make a change would be a very serious matter. The British Admiralty had adopted a standard in relation to flanges which made it almost desirable, and it was quite a common practice for the contractors to adopt multiples of one bolt, because the thickness of flange had to be increased in

(Mr. John Dewrance.)

relation to the spacing of the bolts. It was almost impossible to expect to have the same standard for copper-pipe flanges as for cast-iron flanges; but although those difficulties would no doubt delay anything like the general adoption of the standard, he was certainly of opinion that it would be a very great advantage to the trade generally if some standard was put forward—a well-considered standard—that might be taken as the basis for designers and draughtsmen to use, when there were no reasons why they should adopt any other particular standard. If that alone were accomplished, he thought it would be worth while; and very great praise would be due to the author. Manufacturers could not expect to force their own standards upon their customers, nor force upon them any standard that was adopted; but by referring to some well-recognised standard, it would be possible very often to persuade an engineer to adopt that. There were strong reasons why an engineer should not adopt any particular contractor's standard, when he wished to work to a standard. It happened occasionally that a customer marked off the flanges and drilled the holes of a costly valve, but before it was erected and put to work some other arrangement was required, and he asked the manufacturers to take back the valve and exchange it for something else. He had then to be told that the casing of the valve was absolutely scrap, and nothing could be allowed for it except the metal, simply because he had drilled the holes. It was a thing which might be understood by some people when it was explained, but he had never found anybody understand it very readily.

He thought the difficulty of the 2½-inch pipe was the greatest. The best practice was to have the flanges put together without any jointing material at all. He did not find that red lead or paint was any good for 350 lbs. pressure—the pressure used in his own works. The only thing to be done was to use an absolutely perfect surface, scraped up perfectly, without any jointing material. Even with boiled oil the perfection of the surface was destroyed. When in adopting scraped surfaces, it was highly desirable that the bolts should be as close together as possible, and he did not think a 2½-inch flange with four bolts would be satisfactory for high pressures. The jump from four to eight was one that would require great care from the Committee considering the matter. He recognised all the advantages of the multiples of four, but it seemed to him that in $2\frac{1}{2}$-inch and 2-inch sizes the difficulty was so great that he almost doubted whether it would be possible to avoid having six bolts for those sizes. For all other sizes it was quite feasible. With regard to the diameter and the extra cost, he thought the last speaker had made a mistake in saying that it would be 25 per cent. extra in the cost of pipes. He thought that on iron pipe-lines the extra cost of standard flanges, even if larger with more bolts, would be very little if any more, because the cost of drilling with multiple drills in the factory was very nominal compared with drilling with the ratchet brace on the job. With regard to getting them true, the clearance in the holes ought to be quite sufficient to enable manufacturers to guarantee that their pipes would run for three-quarters of a mile and be perfectly right in the torsional direction. As a manufacturer of steam fittings, he was very much obliged to the author for the great amount of work he had done in collecting information, and he hoped it would lead, with the able assistance of the Institution, to the adoption of a standard which would be as good a compromise as could be possibly arrived at.

Mr. George Addy considered that the manufacturers of pipes generally would welcome standardization. Speaking the other day to the manager of a large pipe foundry, that gentleman said that the great obstacles in the way of any movement of the kind were, particularly with regard to large pipes, the borough surveyors and corporation engineers of this country, who were like little kings, and resented any attempt at dictation. Those surveyors sent their drawings and specifications, and did not welcome any suggestions from the makers. The makers would themselves be very glad if they could have a standard to work to. It so happened that at times there was a large demand for pipes with drilled and faced flanges, and the consequence was that, while the foundry was able to cope with anything of that sort, the machinery—the drilling apparatus, for instance—was altogether inadequate to the business, and weeks elapsed sometimes before the order was despatched. Therefore on

(Mr. George Addy.)

that account manufacturers would gladly welcome any attempt at standardization. He thought an effort should be made with the borough engineers and corporation engineers to begin with, and if that could be done, a great and important step would be made. He was not particularly interested in small pipes, but he had brought two photographs (reproduced on Plate 40) of machines designed for dealing with pipe flanges of large diameter. One of these photographs, Fig. 97, showed the latest type of machine for drilling holes in pipe flanges. As the members knew, drilling holes was an operation which took up time, more particularly in a pipe of 20 or 24 inches diameter and 12 or 14 feet long. In that case the ordinary system had been to have a deep pit close to a radial drilling machine into which the pipe was lowered, and after carefully setting the pipe vertically in position, it was then bolted down and the radial arm moved over the whole face drilling one hole at a time. When one flange had been drilled, the crane was again requisitioned and the pipe hoisted out of the pit, reversed and lowered again ; the setting and bolting down was again to be gone through before the second flange could be drilled. This system was tedious, slow, and very costly, owing to a powerful crane being required for long periods, and the difficulty in fixing in position for drilling. The double horizontal drilling machine illustrated by photograph would drill holes in flanges up to 33 inches diameter and 13 feet long, both flanges at the same time. From actual experience the machine had reduced the price of drilling those long flanges from fourpence per hole to less than a penny. It would be seen from the illustration that the pipe, instead of being handled by the crane and sunk into the pit, was simply fixed on two V blocks and clamped down. There were two horizontal spindles with vertical and transverse traverse, and the consequence was that the man could go to the one end and set one drill at work, and pass to the other end and set the other at work. By the time he had finished setting one drill, the other drill was through. There was no necessity to move the pipe from the time it was fixed on the machine until it was taken off. The other photograph, Fig. 96, Plate 40, showed a double horizontal lathe for facing up to 33 inches diameter and 13 feet long ; in this case the procedure was similar to the drilling process. Instead of taking much time and trouble to fix in an ordinary lathe and then only facing one flange at a time, V rests were used into which the pipes dropped and were clamped down in a few seconds; the heads were then brought up to the flanges, set to work, and both flanges faced at once. Until flange pipes were standardized, it was impossible for makers to put into stock any large quantity of pipes to meet a sudden demand, so the best thing they could do was to see that their works were equipped with the most efficient tools for turning work out expeditiously when orders were plentiful.

Communications.

Mr. Ernest R. Briggs wrote that there was no doubt that one of the most efficient steps taken in what might be termed the "economic progress of mechanical engineering" was that of standardization, and the result of standardization—interchangeability. Owing to the greatness of the field of application of engineering work, and the great increase which was rapidly going on, the difficulty of meeting the wishes and requirements of so many users and manufacturers increased more and more as time passed. It therefore became a matter of urgency that the standardization of such parts, where great advantages were derived from such standardization, should be proceeded with as early as possible, consistent with sufficient experience of usage to warrant the fixing of a standard for future time. It seemed most fitting that the proposition of such work should emanate from the large engineering institutions of the world, and that the particular subject under discussion should be taken up by the Institution of Mechanical Engineers. It was for this reason that it was much to be regretted that the author of the Paper had proposed a new standard, thus adding to the already large number of minor standards in existence—for, as noted in the Paper, every

(Mr. Ernest R. Briggs.)

manufacturer of note had a standard—instead of selecting a standard that had had a large range of use, and above all had stood the test of experience. In England they had no standard, except, as mentioned, those of individual manufacturers, some of which were good; and if they were concerned with this country alone, it would be a good step to accept one of these. As however they were concerned with a much greater application, it became necessary to take a more universal view of the matter. The author gave in Table II (page 307) an American standard which, if not already so, bid fair to become a standard amongst a very large proportion of users of the English system of measurement. There were to the writer no reasons why this standard should be passed over and a new one proposed, but rather the contrary. The author laid down three guiding principles:—

Uniformity in the outside diameter of flanges for varying conditions.

Uniformity in the number of bolt-holes and diameter of bolt circle.

The number of bolts should in all cases be divisible by four.

All of which held good for the American standard of Table II, which could be used for all pressures. There was no doubt to his mind that they should have the three points mentioned as guiding principles; experience bore them out. It frequently happened in large ranges of steam-pipes that branches were taken from the main line of piping, and were separated by a reducing valve and worked at a lower pressure. It was inconvenient to have valves and fittings of various diameters of flanges, for it was generally cheaper for a user to take, say, a high-pressure valve having done duty elsewhere, from his stores and use it on a low-pressure branch, than buy a new valve.

There were three points of criticism in the author's proposed standard, which he would like to draw attention to.

First, the stress on the bolts for the large sizes of pipes seemed too high. The following was considered a good rule:—

$f = 5000d$ lbs. per square inch safe stress, where d = nominal diameter of bolt. f should not exceed 6000 lbs. per square inch.

This would give as follows:—

For	$\frac{5}{8}$-inch bolts	f =	3,125 lbs.
,,	$\frac{3}{4}$,,	,,	3,750 ,,
,,	$\frac{7}{8}$,,	,,	4,375 ,,
,,	1 ,,	,,	5,000 ,,
,,	$1\frac{1}{8}$-inch and over	,,	5,620 ,,

Thus the 20, 22 and 24-inch pipes seemed largely in excess of what might be considered by some to be good practice; for the American standard these pipes gave 4,680, 4,680 and 5,800 lbs. as against 7,136, 7,142 and 6,732 in the author's standard. It should be remembered that these bolts were not always as good as those tested by Professor Goodman, and were manufactured "commercially" and should have a larger factor of safety. It was also perhaps not beside the question to suggest that the human element should be taken into account, and that sometimes more or less unskilled labour was used, with the result that two feet of gas-piping was made to help the spanner.

The second point was that of the distance of centre of bolt to edge of flange. It could hardly be expected that an absolute uniformity could be obtained in this respect, but one would scarcely expect to find such wide variations as existed in the author's standard. Take, for instance, the 7-inch pipe and $\frac{7}{8}$-inch bolt; this gave 1 inch from centre of bolt to edge of flange—or $\frac{1}{8}$ inch more than bolt diameter. The 12-inch pipe gave $1\frac{3}{8}$ inches for same size of bolt, or $\frac{1}{2}$ inch more than bolt diameter. It would be found that the American Table gave more uniform results.

The third point was the limit of the Table. 24 inches was too small to finish at. The standard should be taken to 36 inches at the very least, if not more. A short time ago the writer was engaged in laying out the condensing arrangement for a large central station, in which the main exhaust-pipes were 36 inches in diameter, each of which took three engines of 2,500 I.H.P., each with a 26-inch exhaust from the engine.

Great as were the advantages of a standard for all users of the English measurements, there still remained the disadvantage of want of interchangeability between their system and the metric, and he

(Mr. Ernest R. Briggs.)

was afraid that the author's suggestion of departing from the round number in millimètres would find small favour with users of the metric system, and seeing the large amount of valves and fittings exported from this country and the growing amount from the States to the Continent, it was a matter of surprise that export manufacturers had not approached the Continental users in the matter of a metrical standard for such goods.

It was to be hoped that the Institution could see its way to appoint a small Standing Committee on standardization of matters of this description, and try to bring order out of chaos, not from the somewhat narrow view of this country alone, but truly international.

Mr. F. Herbert Marshall wrote that he offered the following remarks solely from the point of view of the user of pipes, without considering the maker thereof. He submitted a copy of the standard Table of pipe flanges (page 364) that his firm, Messrs. Wilsons, Pease and Co., had been using for many years now; for which Table he was in the first place indebted to the late Mr. Joseph Wright of Tipton, whose practical knowledge of steam engineering was very extensive. Seeing that bends and specials were sold at a much higher price per ton than were straight flanged pipes, the Table here given had been so arranged as to reduce the former to the smallest practicable dimensions, whereby a considerable saving in total cost of a range of piping was often effected. The strengths given, he might say, were intended for pressures up to 100 lbs. per square inch of steam.

The points he desired to emphasise were:—

1. Bolt-holes to be a multiple of four.

2. „ „ „ "straddle" the centre line.

3. Flanges same diameter for all pressures, varying in thickness only.

4. Bolt-holes in cast flanges to be oblong and tapered as shown in Table XIV (page 364). This greatly facilitated chipping, if holes were not quite correct, which often happened in castings.

5. Turned facing from bolt-holes to inside only, the outer part of flange face being set back. This reduced cost of "facing."

6. Reducing tee pipes, etc., to have the smaller branch of the same length as on list for the larger branch or body.

7. Bends, tees, crosses, etc., all to be of the same length from centre of pipe to face of flange. The lengths given in the list were the shortest that permitted use of spanner.

Item 5 above meant the same as shown in the Paper, Fig. 38, Plate 37. Figs. 40 and 43 were, he thought, very objectionable if ever a joint needed remaking in a range of steam-piping, as the joint could not be sprung open sufficiently for the recess to be cleaned out. Fig. 48, Plate 37, he had never seen tried, but it struck him as the best of the lot; the loose flanges would be very convenient for adjusting positions of bolt-holes and for access to joint ring if required; and the joint ring could not blow out. For pressures up to 100 lbs. he had frequently on emergencies made up a flanged pipe of special length by cutting off one end of an old pipe, slipping a loose wrought-iron flange on to the pipe, and then contracting a wrought-iron hoop on to the cut end, and facing this and the end of the pipe in the lathe. Such a pipe answered very well, and obviated a serious stoppage, which in blast-furnace practice was a thing to avoid at almost any cost. The loose flange also got over any difficulty with the holes in both flanges not being in line with each other, which sometimes occurred.

Other points of importance were such as making all valves to open the same way, and clearly marking on the valve which way this was. Some of the leading makers of sluice-valves were great sinners in this respect, as well as in having an odd number of bolts in valve flanges. Also when a reducing tee pipe was required it should be made a standard tee of the larger size with the branches tapered down. Failing this, there was danger of not having full area at the junction. He begged to thank the author for his Paper and efforts towards introducing uniformity in an important detail of engineering; and he could promise him that when a standard list was agreed upon he would do his part in having it adhered to.

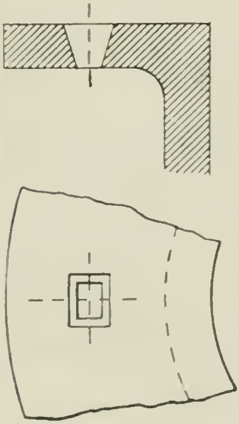
(Mr. F. Herbert Marshall.)

TABLE XIV.

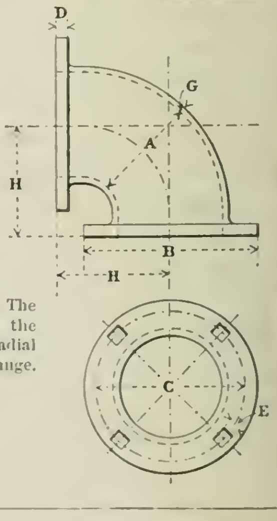
Standard Flanges used by Messrs. Wilsons, Pease and Co., Tees Iron Works, Middlesbrough.

Working pressure up to 100 lbs. per square inch of steam.

Diameter of Pipes.	Diameter of Flange.	Centres of Bolt-Holes.	Thickness of Flange.	Size of Bolt-Holes.	Number of Bolts.	Thickness of Body.	Length of Bend.	Diameter of Pipes.	Diameter of Flange.	Centres of Bolt-Holes.	Thickness of Flange.	Size of Bolt-Holes.	Number of Bolts.	Thickness of Body.	Length of Bend.
A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
ins.	ins.	ins.	ins.	ins.		ins.	ins.	ins.	ins.	ins.	ins.	ins.		ins.	ins.
$1\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	4	$\frac{8}{32}$	$3\frac{1}{8}$	9	15	$12\frac{3}{4}$	1	$1\frac{1}{8}$	8	$\frac{16}{32}$	$9\frac{1}{2}$
2	$5\frac{1}{4}$	4	$\frac{1}{2}$	$\frac{1}{2}$	4	$\frac{9}{32}$	$3\frac{5}{8}$	10	16	$13\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	8	$\frac{5}{8}$	10
$2\frac{1}{2}$	$6\frac{1}{4}$	$4\frac{7}{8}$	$\frac{9}{16}$	$\frac{9}{16}$	4	$\frac{10}{32}$	$4\frac{1}{4}$	11	$17\frac{1}{4}$	$14\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{8}$	8	$\frac{11}{16}$	$11\frac{1}{4}$
3	7	$5\frac{1}{2}$	$\frac{5}{8}$	$\frac{11}{16}$	4	$\frac{11}{32}$	$4\frac{3}{4}$	12	$18\frac{3}{4}$	$16\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{8}$	8	$\frac{11}{16}$	$11\frac{5}{8}$
$3\frac{1}{2}$	8	$6\frac{1}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	4	$\frac{11}{32}$	$5\frac{1}{2}$	14	$20\frac{3}{4}$	$18\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{8}$	8	$\frac{3}{4}$	$12\frac{5}{8}$
4	$8\frac{3}{4}$	7	$\frac{3}{4}$	$\frac{7}{8}$	4	$\frac{12}{32}$	$5\frac{7}{8}$	16	$23\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{1}{4}$	12	$\frac{3}{4}$	$14\frac{1}{4}$
5	$10\frac{1}{4}$	$8\frac{1}{4}$	$\frac{7}{8}$	1	4	$\frac{12}{32}$	$6\frac{7}{8}$	18	26	23	$1\frac{1}{2}$	$1\frac{1}{4}$	12	$\frac{3}{4}$	$15\frac{3}{4}$
6	$11\frac{3}{4}$	$9\frac{1}{2}$	1	$1\frac{1}{8}$	4	$\frac{13}{32}$	$7\frac{7}{8}$	20	28	25	$1\frac{1}{2}$	$1\frac{3}{8} - 1\frac{1}{2}$	12	$\frac{25}{32}$	$16\frac{3}{4}$
7	$12\frac{3}{4}$	$10\frac{1}{2}$	1	$1\frac{1}{8}$	4	$\frac{14}{32}$	$8\frac{3}{8}$	22	30	27	$1\frac{1}{2}$	$1\frac{3}{8} - 1\frac{1}{2}$	12	$\frac{26}{32}$	18
8	$13\frac{3}{4}$	$11\frac{1}{2}$	1	$1\frac{1}{8}$	8	$\frac{15}{32}$	$8\frac{7}{8}$	24	$32\frac{1}{2}$	$29\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{8}$	16	$\frac{7}{8}$	20



Bolt-holes tapered and slotted as per sketch. Small sizes given in line E in all cases. All bolt-holes in pipe flanges to be rectangular and oblong, $\frac{1}{8}$ inch longer tangentially than radially, and tapered $\frac{1}{16}$ inch on every side, with larger size on face of flange. The dimension figured is the smallest, namely, the radial dimension on back of flange.



Mr. H. M. ROUNTHWAITE wrote that he brought out his first standard list of flanges for factory use in 1878, and as he had been testing it, adding to it as required, and modifying it as extended experience indicated, up to the present time, he thought it was now about as perfect as such a table could be made.

He desired to combat the idea that it was possible to fix a standard that would be suitable for all sorts of pipes and flanges, or for all branches of trade. Any such attempt would end in the production of a standard that would be impartially ignored by all branches. As emphasising this point he must say that, in dealing with marine work, for instance, he would feel himself quite unable to use such a standard as that proposed by the author of the Paper. Considerations of weight and cost put that proposal out of the question. Diameters were greatly larger than necessary, and thicknesses of flanges (necessary to the author in order to obtain the very wide pitches he suggested) were also far beyond any practice he had ever met with, and where gun-metal or bronze (flange metal) flanges were in question would be ruinous.

He also thought the idea of using numbers of bolts which should always be divisible by four to be inconvenient and impracticable, as the result would be either wildly fluctuating thicknesses or pitches. The number of bolts should be whatever was requisite to give a suitable pitch with a suitable thickness of flange. The pitch of bolts should bear some relation to the diameter of bolt, as well as to the thickness of flange and to the pressure.

A formula which he had found to give very satisfactory results for any pressure between 10 lbs. and 300 lbs. per square inch was:—

$$\text{Pitch} = \frac{10\sqrt[3]{d t^2}}{\sqrt[4]{\ }} + 0{\cdot}5.$$

where Pitch = length of chord from centre of one bolt to centre of next in inches.

d = diameter of bolt in inches.

t = thickness of flange in inches.

P = working pressure in lbs. per square inch.

(Mr. H. M. Rounthwaite.)

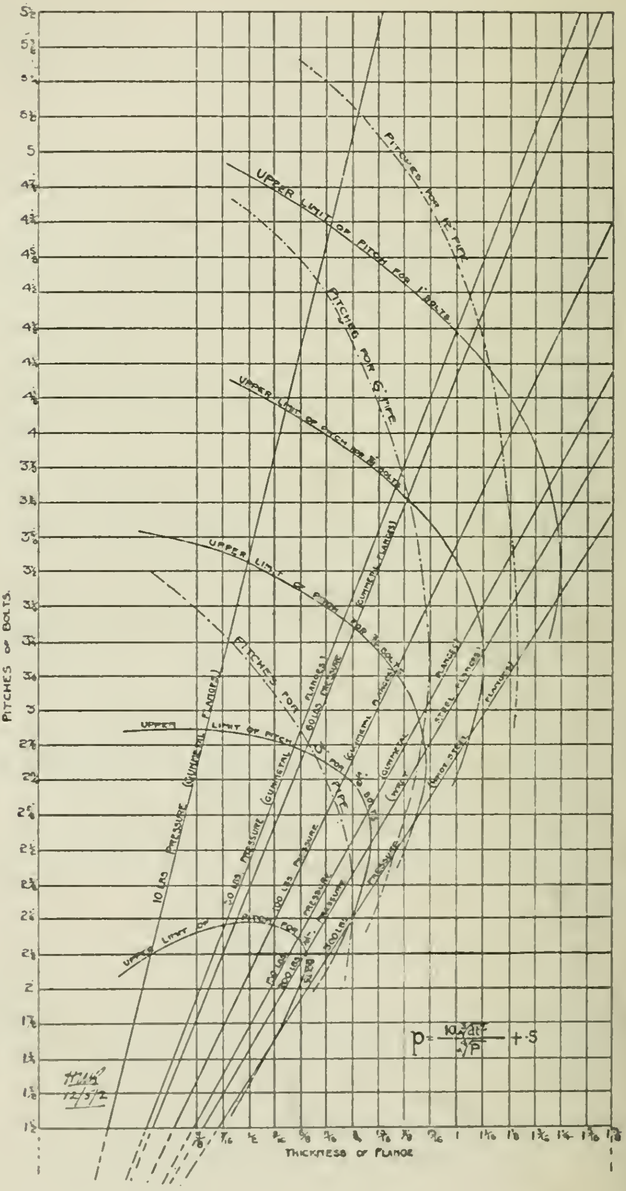


Fig. 98.—*Thickness of Pipe-Flanges, and Pitch of Bolts.*

(Derived from formula.)

This was not perhaps a formula that was mathematically correct in form, and that *ought* to give correct results, but it was an empirical formula which *did* give results that years of experience had shown to be satisfactory. It provided for a water-pressure test of double the working pressure in all cases.

He believed that for all except cast-iron pipes and flanges there should be three distinct standards—one for pressures up to 50 lbs., one for 51 lbs. to 150 lbs., and one for 151 lbs. to 300 lbs. Cast-iron pipes should either have one or more standards to themselves, or possibly the cast-iron standard might be that for a pipe of $\frac{1}{4}$ inch or $\frac{1}{2}$ inch greater diameter on the other standards. $\frac{3}{8}$-inch bolts should not be used at all, and $\frac{1}{2}$-inch bolts should not be used for pressures over 200 lbs., and when they were used, should be confined to pipes under 2 inches diameter or bore. All his results had been obtained with flanges machine-faced and scraped up fairly true, and with joints made with 70-mesh copper-wire gauze painted with red-lead paint of the consistence of cream. He thought that these two preliminary points, namely, the condition of the flange surfaces and the description of the jointing material, must be decided before it was possible to discuss any dimensions of flanges or bolts. The drilling or non-drilling of the flanges was a point that every manufacturer must settle for himself.

Fig. 98 (page 366) showed the proportions given by the previously mentioned formula.

Mr. Atkinson, in reply, wrote that the discussion of a subject such as this would inevitably disclose many and varied opinions; but, although this had been the case, yet it was satisfactory to observe a unanimous desire for the adoption of a standard. Before replying to the discussion in detail, he would like to correct an impression which appeared to have been formed, namely, that the standard he had advocated was designed by his firm, and that it had been adhered to in disregard of all the information that had been collected upon the subject. This was an entirely erroneous impression, although it might be said that some justification might be found for it in the fact that Tables IX, X, and XI (pages 317–319)

(Mr. Atkinson.)

were headed as "Standard Flanges adopted by the Author's Firm." That the standard therein given had been adopted by his firm was correct, and the support thus given to it by the test of practical experience must add to its value. The origin of the standard might be stated briefly as follows. For many years the firm alluded to used the standard of Messrs. Newton, Chambers and Co. exclusively, but in time it was found defective, especially for pressures over 50 lbs. Consequently that of Messrs. J. Hopkinson and Co. was substituted, but this in turn was proved to be troublesome and inefficient in various ways; and, a favourable opportunity arising, the author's colleague, Mr. Nesbit, introduced a discussion on the subject at a meeting of the British Institution of Heating and Ventilating Engineers. Following this, he himself prepared a further Paper, and arranged a suggested standard, which was laid before the Institution named, but was not adopted. It, however, formed a basis for a standard which, after considerable discussion, was adopted by that Institution; and it was this standard which now formed the subject of his proposals. It should be added, with respect to the information obtainable on the question, that the Institution referred to carefully considered the various standards in use in England and America before arriving at a decision.

Referring to a remark made by Mr. Hatch (page 351), that he and the author approached standardization from different standpoints, he thought this was hardly the case, as he had found the difficulty to be not altogether in the manufacture of flanged goods, but in their erection, replacement, and purchase within a reasonable time. Indeed, it appeared to him that the question was more important from the consumers' point of view than from that of the manufacturers'.

Mr. E. R. Briggs (page 359) suggested using American standard No. 2, but, as stated in the Paper, he himself considered the diameter of flanges in this standard exceeded that of practical requirements, and a standard involving any superfluous metal was liable to failure. This standard was of recent origin, and American manufacturers were usually keen in insisting that their goods should not contain metal unnecessary for practical requirements, and he believed that their high pressure standard would be reduced as regards diameters of flanges, before it was universally adopted by them. As to the stress on the bolts for large sizes of pipes, he would point out that the bolts tested by Professor Goodman were of a "common" quality, and such as were generally used for this class of work; nevertheless, the standard provided for a large factor of safety for bolts of this quality.

Objections were raised to the fact that uniformity did not occur in the distances from centre of bolt to edge of flange. This was accounted for by the fact that it was desirable to keep the bolt circle as small as convenient, and as far as possible to preserve the outside diameter of flanges in even inches, or fractions of not less than half an inch. Then as to the limit of the Table, it must be admitted that pipes above 24 inches diameter were the exception rather than the rule, but no difficulty stood in the way of increasing the schedule to 36-inch or even 48-inch pipes. Before the Committee met, he would prepare an extension of the standard to suit the larger sizes.

With regard to breakdowns occurring in flanged pipes and fittings, Mr. Stromeyer (page 345) mentioned only fifty explosions of steam-pipes on land boilers as having taken place during the last seventeen years, but it must be remembered that there were thousands of instances of pipes, valves, or fittings breaking down, or having to be replaced, which did not come under the official notice of the Board of Trade. Doubt was also expressed whether any firm would care to stock pipes on the off-chance of being called upon to supply them at once. It was, however, a well-known fact that a large number of firms did hold stocks of flanged pipes and fittings, the pipes being usually of 6-foot and 9-foot lengths; while large stocks were regularly held of fittings and valves. As to the practicability of placing the holes in the flanges so that any pipes or fittings bolted together should be interchangeable, he did not see any difficulty, ordinary care, of course, being taken in drilling the holes to template. It would be understood that a fine grade of accuracy was not often required; in fact, in the average run of steam-pipe for pressures up to 120 lbs. the holes in the flanges were often cored out by the foundryman.

(Mr. Atkinson.)

Objections had been raised to the principle of the number of bolts being a multiple of four, chiefly for the reason that eight bolts were required for 3-inch pipes, where six would be sufficient, and also on the ground of a consequent additional expense. This objection would be found on examination to be more apparent than real. Thus, if it were assumed by way of example, that a mile of 3-inch pipe had to be fixed, and that the material was cast-iron, it would doubtless consist chiefly of lengths of 9 feet; and, allowing for connections, it might be said that the joints would average one in 8 feet, that is, 660 joints would be used. If four $\frac{3}{4}$-inch bolts were used in each joint, the total weight of bolts required would be 2,310 lbs.; if six $\frac{5}{8}$-inch bolts, 2,145 lbs.; or, in case of eight $\frac{1}{2}$-inch bolts, 1,650 lbs. It would thus be seen that, instead of the cost being increased by adopting eight bolts, the actual cost of the bolts themselves would be less, and the saving thus effected would be sufficient to pay for the extra labour in inserting the two additional bolts in each joint. In the case of wrought-iron pipes, the joints would be less frequent, and the small additional expense in the extra bolts would be more than compensated in the reduced cost of manufacture upon the adoption of a standard.

Mr. Incledon (page 349) laid stress on the diameter of flanges for 3-inch pipes being put at 8 inches, whereas in his opinion 7 inches would be ample for wrought-iron pipe. This might be so in the case of a wrought-iron pipe screwed into flange, but 7 inches was too small a diameter for a flange on a 3-inch cast-iron valve, and it was also too small for a steel pipe when the flanges were formed of angle-irons riveted on to the pipe. It appeared desirable that any standard should take into account these various conditions, as well as the fact that it was frequently necessary to use this standard in connection with cast-iron valves and fittings, although in many cases wrought-iron pipe was used.

Mr. Hatch (page 351) expressed a fear that the engineers in charge of large power stations might be careless, and fix low-pressure fittings in positions where those of high pressure were required. He himself did not think this risk would be increased by the flanges being standardized, as it was now becoming very common for makers to cast on to pipes, valves, and fittings, the maximum pressure at which they were supposed to be capable of working. Further, the thickness of the flanges, and the size of the bolt holes would be less for the low-pressure valve or fitting, and this would also tend to lessen the danger of error. Mr. Hatch was also afraid that if the standard suggested by the author were adopted, the cost of pipes, valves, and fittings would be increased. This would assuredly not be the case. On the contrary, the cost would be decreased by the greater efficiency in their manufacture. As to the standard proposed being used for copper and brass, cognizance must be taken of the fact that copper and brass valves had often to be attached to cast-iron, steel, and wrought-iron flanges and fittings; and in this connection it must not be forgotten that valves constructed wholly of brass were usually of the smaller sizes, in which the extra amount of metal, beyond what was actually essential, would be very slight indeed.

In explanation of his having directed attention in passing to the list of standard flanges that was laid before the German Society of Engineers by Messrs. Schäffer and Budenberg, he might add that his object was merely to show that the question of arranging the bolt holes in multiples of four had already been advised, but he did not regard that standard generally as one that could be adopted with advantage.

CONVERSAZIONE.

A Conversazione was held at the Institution on Friday, 16th May 1902, when the Members and their friends were received by the President and Mrs. Maw. During the evening the Band of His Majesty's Scots Guards performed a selection of music, and vocal music was rendered in the Library. Arthur Gulston, Esq., of Newcastle-upon-Tyne, kindly gave in the large Hall a brief description of Ice Breaking in the Arctic Region, which was illustrated by lantern slides; and a room was set apart for Electrophones. The number of Guests was about 700.

NOTES ON TURNING MIRRORS FOR SEARCH LIGHTS.

By Mr. ARTHUR E. PETTIT, *Associate Member*,
of Germiston, Transvaal.

After the first incursions of the Boers in December 1900, with the object of wholesale destruction of the surface plants of the mines on the Rand, the attention of the authorities was called to a question of defence for these mines, and among other precautions searchlights were erected at various points of vantage along the reef. Most of these searchlights were fitted with glass mirrors of the Mangin or Parsons type, but during the first serious attack the enemy shot at the searchlight and shivered the mirror, necessitating the immediate local construction of metal mirrors.

As it was found impossible, owing to the lack of necessary appliances and requisite skilled labour, to erect a plant for the electro-deposition of a paladium-faced copper mirror on carbon-coated glass, other methods had to be resorted to. Attempts were made to spin mirrors from thin-plate copper and brass, but owing to the lack of skilled labour in this trade the mirrors were not satisfactory. Electro-deposition on gutta-percha also met with a similar result, owing to the springing of the mould and the porosity of the deposit. Dies were then cast and an attempt made to press out the parabola, but owing to the spring and buckle of the copper plate this method also proved futile.

After these failures the work of turning out a correct parabola was undertaken in the shops of the Simmer and Jack East Mine at Elandsfontein, but as no suitable appliances were obtainable, and owing to the war the requisite gear unprocurable, everything connected with the turning and buffing had to be designed and constructed on the spot, causing much delay and inconvenience. The required parabola for a 13·75-inch focal length 24-inch diameter mirror was carefully calculated, and a strickle made from which a mould was set out for a brass casting to finish one-half inch thick; after various attempts an alloy composed of 10 per cent. copper, 2 per cent. block tin, and 88 per cent. best scrap brass was found most satisfactory, and in order to avoid blow-holes in so thin a casting, two hundred small vent-holes were left and the mirror cast inverted, four legs being left on the convex side to bolt to the face-plate of a lathe. A steel plate was then marked off to the correct parabola to form a parabolic slot 1·3 inches diameter and attached to the cross slide of the slide-rest (the feed-screw being removed), thus leaving this slide free only to move the full depth of the parabola in the template, which was rigidly fixed to the saddle extension, the lower slide being used automatically for the cross cut, and the saddle screw to bring the tool to the cutting position and for advancing the feed. Three light cuts were then taken, and before the final skimming a hard steel burnishing tool was fixed in the tool-holder and run several times across the face to close up all small blow-holes. The casting was then ground with various degrees of emery cloth over a wood block fixed in the tool-holder, until all but the minutest scratches were removed; this grinding tool was always made to follow the path of the parabola. The tool-holder was then removed, and a leather buff substituted driven off a two horse-power electric motor, the feed-screw of the lower slide being removed and a bell crank lever substituted; as it was found that a regular feed was inclined to ring the mirror, this buff and the finishing buff of unbleached calico were both kept moving in the path of the parabola, giving an even pressure all the time on the mirror. The first mirrors were silver-plated, but as this was found in some cases not entirely satisfactory, owing to the excessive tarnishing, nickel-plating was substituted, which gave more satisfactory results.

On comparing the intensity of the light thrown by one of these mirrors, it was found to be approximately 80 per cent. of that thrown by one of the best glass mirrors, and besides costing about half the amount of one of these glass mirrors, notwithstanding the high rate of wages and the proportion of the initial construction of the manufacturing gear, had the overwhelming advantage of that, although fired at by the enemy, it would not vary appreciably in projecting power, the bullet passing clean through and the reflecting surface being reduced by only the small area of the bullet-hole. So satisfactory have these mirrors proved that 12-inch mirrors made in the same way are now used on some of the armoured trains, and give excellent results.

The Paper is illustrated by Plate 41.

MEMOIRS.

George Cooper was born in Preston on 22nd May 1836. After receiving an elementary education, he spent three years as junior clerk in a yarn warehouse in Preston, after which he went to Rossall School for a year and a half. In 1853 he entered the works of Messrs. Daniel Adamson and Co., Newton Moor Iron Works, but towards the end of 1855 changed to Messrs. Benjamin Hick and Son, Soho Iron Works, Bolton; and, excepting an interval of nine months, he remained with this firm for five years and a half. In March 1861 he entered the service of Mr. Edmund Sharpe, at the Phœnix Foundry, Lancaster, as draughtsman; on the manager retiring a few months later he remained in charge of the technical work of the establishment until June 1862, when, in view of the general depression of trade throughout Lancashire due to the war in the United States, he resigned his post and emigrated to Buenos Aires. Soon after landing he obtained employment as second engineer on the "Pampero," a river steamer plying between Buenos Aires and Monte Video. Six months later he became draughtsman to the late Mr. John Coghlan for a short time, when he entered the service of Mr. Frank Parish, H.B.M.'s Consul, as Consul's clerk, and clerk to the British Post Office, during the absence of the permanent officer. While with Mr. Parish he assisted Mr. Alfred Rumball in connection with the plans for the construction of the Buenos Aires Great Southern Railway. In 1864 he entered Mr. Rumball's service on the resident engineer's staff, and after a few months became his chief assistant engineer, remaining with him until the completion and opening of the Great Southern Railway to Chascomus, in December 1865. At that date he entered the railway company's service as locomotive foreman, and took charge, in addition to the locomotive department, of the general stores and the stations at North and South Barracas. To these duties was added shortly afterwards the charge of the permanent way. In 1867 he was appointed assistant to the general manager, and for nine months took charge of the railway as acting general manager. In September 1868 he retired from the Great Southern Railway to take charge, as constructing engineer and general manager, of the Central Argentine Railway, for the contractors, with whom he remained until the line had been completed to Cordoba, and handed over to the company.

In 1872 he re-entered the service of the Buenos Aires Great Southern Railway to take charge of the construction of extensions, and in case of the retirement of the general manager—Mr. E. Banfield—to succeed him as chief engineer and general manager of the railway. Mr. Banfield's health broke down so rapidly that Mr. Cooper was obliged to take over his duties at once, and remained with the company until his retirement in 1886, when he returned to England. From the beginning of 1887 to 1892 he was engineer in London to the firm of Messrs. Lucas, Gonzalez and Co., the contractors, among other works, for the construction of the prolongation and branches of the Central Northern Railway of the Argentine Government. He visited the River Plate in 1890 as one of a commission of the Central Argentine Railway, and again in 1894 was sent out by that company to take charge of the railway during the visit of the general manager to England. He was a director of several of the Argentine Railways. His death took place at his residence in London, after a year's illness, on 3rd April 1902, in his sixty-sixth year. He became a Member of this Institution in 1877.

BRYAN DONKIN was born in London on 29th August 1835, and was the son of the late Mr. John Donkin, and grandson of the late Mr. Bryan Donkin, F.R.S., who in 1803 founded the well-known works at Bermondsey, and invented the first practical paper-making machine. After having been educated at various schools, he studied at University College, London, and later on at the École Centrale des Arts et Manufactures, where he passed in French an examination for Technical Education. At the age of twenty-two he entered his grandfather's engineering works, and went through the various workshops. In 1859 he was sent to St. Petersburg to superintend the erection and completion of the largest paper-mill in Europe for the making of Imperial Bank notes and State papers. He continued in Russia for three years, acting as resident engineer at the paper-mill, which employed nearly three thousand workpeople. The paper-mill and machinery are still in working order, and all the paper money in Russia is made there.

In 1868 he became a partner in the firm, and when it was converted into a company in 1889 he was made chairman, and continued to hold this position after its amalgamation with Messrs. Clench and Co., of Chesterfield, in 1900. In 1871 the firm introduced the Farey engine—Mr. Farey being a partner. The tests on it were the forerunners of the many numerous trials which he conducted during his life. He was specially interested in steam-boilers, gas-engines, condensation in steam-engine cylinders, and centrifugal fans, and had erected an experimental engine at the Bermondsey Works, where for many years a large number of experiments were carried out. In 1888 he perfected his "Steam Revealer,"* a simple apparatus by which he was able to make diagrams illustrative of the extent of condensation under varying conditions; and the long series of trials made by himself, and in collaboration with others, including Professor Alexander B. W. Kennedy, Professor T. Hudson Beare, Lieut.-Colonel English, &c., has borne direct practical results. Early in the "nineties", he directed his attention to the subject of internal-combustion motors, and read in 1894 before the Incorporated Institute of Gas Engineers a Paper on the comparative merits of steam and gas motors. In 1893 he brought out his standard work on "Gas, Oil, and Air Engines," and translated Diesel's work on "The Theory and Construction of the Rational Heat Motor." At the same time he was engaged in original research work on internal-combustion engines, and acted as a judge for the Royal Agricultural Society and at other competitions. He was joint author with Professor

---

[*] Proceedings 1900, page 509.

Kennedy of "Experiments on Steam Boilers," and published in 1897 his book entitled "Heat Efficiency of Steam Boilers," a work giving details as to the heat value of fuel, analyses of gases, evaporation, &c. He introduced at his works the Perret system of forced draught, the manufacture of which apparatus was taken up by his firm and successfully developed. On this subject he read a Paper in 1892 before the North of England Institute of Mining and Mechanical Engineers. In conjunction with Mr. J. Holliday, he also did some experimental testing with fuel calorimeters. Centrifugal fans formed the subject of other investigations; while about twelve years ago he worked upon the velocity of air through pipes with anemometers at the Vauxhall Waterworks. The results in all three cases were given in Papers to the Institution of Civil Engineers. In later years motor cars absorbed much of his attention, both as a member of the Automobile Club and as a manufacturer of the motor.

To this Institution he contributed several Papers. Among them are the following:—"Cylinder Heat Losses" (Proceedings 1893, page 480); "Steam-Engine Experiments" (1895, page 90). In conjunction with Professor Beare he made a Report to the Steam-Jacket Committee on "Steam-Jacketing a Locomotive Engine" (1896, page 466); and collaborated with Lieut.-Colonel English on a Paper on "Heat Transmission" (1896, page 501). To Professor Hele-Shaw's Paper on "Road Locomotion" he added an Appendix on Tests of Motor Carriages at Richmond and Birmingham (1900, page 238). He frequently took part in the discussions at this Institution and at the Institution of Civil Engineers. He was elected a Member of this Institution in 1873; and was a Member of Council from 1895 to 1901, when he became a Vice-President. In addition, he served on various committees, such as the Research Committee on the Value of the Steam-Jacket, on Marine Engines, on Gas-Engines, and on the Steam-Engine Research Committee. He was a Member of the Institution of Civil Engineers, and acted on their Committee on the Efficiency of the Steam-Engine, and on the Committee for Reporting on Standard Forms for Tabulating Results of Trials on Steam-Engines and Boilers. In addition, he was a

Watt medallist and Telford and Manby prizeman, and was a Member of the American Society of Mechanical Engineers, of the Verein der deutschen Ingenieure, of the Société Industrielle de Mulhouse, and a Member of the Jury for the English Section at the Paris Exhibition of 1900. He had been lately troubled with an affection of the heart, and had been advised to give up some of the work to which he had devoted himself. Having had occasion to visit Brussels, in connection with an engine trial, he retired to his room at night, after having been engaged on experimental work during the day, and expired before medical aid could reach him. His death took place on 4th March 1902, in his sixty-seventh year.

John Hopkinson was born in Manchester on 24th February 1824. At an early age he showed much inclination to mechanical pursuits and aptitude in constructive work. In 1840 he was apprenticed to the firm of Wren and Bennett, engineers and millwrights, of the London Road Iron Works, Manchester, and rapidly earning the complete confidence of his principals was even during his apprenticeship entrusted with much important executive work, including the erection of the India Mills, Stockport, built to hold 70,000 spindles and 1,000 looms, then one of the largest mills in the country. He designed the buildings and supervised the erection of the iron-work and the gearing. In 1848 he became a partner in the firm, together with the late Mr. Henry Wren, the style of the firm becoming Wren, Wren and Hopkinson, and subsequently Wren and Hopkinson; and he so continued until the end of 1881, when he retired, but continued his engineering work as a consulting engineer in partnership with his son Charles who had been his assistant for some years.

During the thirty-three years that he was the active head of the firm of Wren and Hopkinson in all technical matters, they were engaged upon many important engineering developments. They designed and constructed the machinery for grinding and polishing the lenses for the dioptric lanterns of lighthouses for the late Sir James Chance, with whom Mr. Hopkinson had for many years most cordial business relations, which ultimately led to his eldest son, the late Dr. John Hopkinson, becoming manager and scientific adviser of Messrs. Chance Brothers, lighthouse and optical glass departments. During this period the firm devoted much attention to the construction of Cord Power Cranes on Ramsbottom's principle, hydraulic presses for baling raw cotton and piece goods, and slate working machinery, and particularly to the compounding of mill-engines under Crossland's patents, by the addition of an oscillating high-pressure cylinder to the low-pressure engines then usually in vogue. Mr. Hopkinson, together with Mr. Henry Wren the elder, were recognised in Lancashire and elsewhere as the leading authorities on all questions of mill gearing, before rope driving had become usual, and there were few privately owned mills in the North of England, which had not at one time or another the benefit of his practical experience and knowledge, amongst which may be specially mentioned the spinning and cotton thread mills of John Dewhurst and Sons of Skipton, and the factory of the York Street Flax Spinning Company at Belfast, for both of which he designed the buildings. Perhaps the most important engineering work to which he devoted his attention was the design and equipment of railway goods stations and sorting yards. He was constantly consulted by the Lancashire and Yorkshire Railway Company with regard to their goods stations, and re-arranged and equipped with revolving capstans and power cranes their stations at Howard Street, Liverpool, Oldham Road and New Bailey Street, Manchester. His scientific knowledge and engineering ability were applied in many other directions outside the limits of his own business. For many years he was chairman of the Chatterley Iron Co., and under his supervision many improvements were introduced in the mechanical arrangements at their various collieries. For thirty-six years he was connected with the Carnforth Hematite Iron Co., at first as vice-chairman and subsequently as chairman. He was also for a time a director of the Union Plate Glass Co.

Though the great developments in electrical engineering were subsequent to the most active period of his career, he always took the keenest interest in them. One of his first essays in practical work during his apprentice days was the construction of a cylinder frictional electrical machine, and one of the latest designs of his old age was an electrical locomotive. Three of his sons have been closely associated with electrical engineering, and several of his apprentices, which was always a matter of gratification to him. He will long be remembered amongst the most progressive of engineering employers in Manchester for his generous and far-seeing views in regard to the relations of employers and employed, and the part he took in establishing the fifty-four-hour week. The interests of his own employés and those of the companies with which he was associated were always promoted by him with characteristic generosity and disinterestedness.

Though occupied with private business affairs demanding close attention, he devoted no small portion of his life to the public service of his native city, and freely gave of his ripe experience and knowledge for the public welfare. In 1861 he was elected unopposed as Councillor, and continued to be re-elected, always without opposition, until 1872 when he became Alderman, which office he held until his death. Thus for over forty years he was continuously engaged in municipal affairs, and in the year 1882–3 he was Mayor. As member of the Free Libraries, the Watch, Fire Brigade, Finance, Ship Canal Committees and of the Art Gallery Committee, of which he was the first chairman, he did manifold service to the good government of Manchester; but probably the most permanent record of his public work is to be found in the improvements in the course of the River Medlock, which he initiated and supervised, and which entirely obviated the disastrous floods which were previously of frequent occurrence, in the construction of the large gas works at Bradford Road, and in the laying out and widening of the streets in the township of Chorlton-upon-Medlock in which he long resided. His death took place at his residence at Bowdon, near Manchester, on 14th March 1902, at the age of seventy-eight. He became a Member of this Institution in 1856; and was also a Member of the Institution of Civil Engineers.

Herbert William Lewis was born in Birmingham on 18th August 1847. Having been educated at a private school and at the

Midland Institute, Birmingham, he served his time from 1861 to 1868 in the engineering works of Messrs. James Watt and Co., Soho, Birmingham. In 1869 he went to Messrs. Tangye Brothers' Works, where he worked as a draughtsman and also as fitter. In the same year he proceeded to India, acting for a short time as engineer in the Bombay Marine, and then received the appointment of mechanical superintendent of H.M. Cotton Gin Factory at Dharwar. In 1874 he was promoted to the post of superintendent of this factory, which position he held until 1876, when he became superintendent of the industrial school at the same place. In 1883 he was appointed superintendent of H.M. School of Industry at Ratnagiri, South Koncan, which was one of the pioneer institutions for technical instruction in engineering and the domestic arts in India. He held this position to the time of his death, but during the last four years had at intervals acted as chief inspector of boilers for the Bombay Presidency, in the absence of the permanent official. His death took place from dysentery in Bombay on 8th March 1902, in his fifty-fifth year. He became a Member of this Institution in 1895.

ALFRED MUIR was the fourth son of the late William Muir, engineer, founder of the firm of Messrs. William Muir and Co., engineers' tool makers, Manchester. He was born on 29th May 1840, at Pimlico, London, where his father was engaged at that time as manager for Mr. Bramah, the inventor of the celebrated Bramah lock and of the important improvements in the hydraulic press, which made it commercially useful. Later on in June 1840, the late Sir Joseph Whitworth, then Mr. Joseph Whitworth, induced Mr. Muir, Senr., to join him at his works in Manchester, but in June 1842 he left Sir Joseph and started business on his own account in Manchester. Alfred Muir was therefore brought up in Manchester, and after completing his education at the Chester College, he served his time in his father's works. Then, to gain experience, he worked for some time as a journeyman mechanic at Messrs. Penns' Marine Engineering Works, Greenwich. On his leaving that firm, he was appointed manager of his father's works, and when the latter retired from the business, he succeeded him, and eventually, on its being converted into a private company, he was appointed Chairman and Managing Director, which position he held at the time of his death. He took great pride in turning out work only the best of its kind, both in finish and accuracy of workmanship, and so continued the high reputation that the firm's tools had acquired for such qualities. He also brought out several clever inventions, notably improvements in cutters for milling, in couplings for drilling and milling machines, and in capstan slide-rests for lathes. He was lately selected by the War Office as a Member of the Screw Committee appointed by them to make experiments and report on a Standard Screw that should be adopted by the country, when his special experience was, and if he had been spared, would have been, of the greatest value.

He took no prominent part in politics or municipal work, but devoted himself unremittingly to business, to which he was much attached, and he died suddenly on 10th May 1902, in his sixty-second year, at Harrogate, where he was staying for the benefit of his health, after returning from Egypt, where he had been for three months for the same purpose, but had returned with no improvement in his condition.

He became a Member of this Institution in 1873; and was also a Member of the Iron and Steel Institute.

Francis Johnstone de Soyres was born at Clifton, Bristol, on 28th October 1839; and was educated there at a private school, and at the Bishop's College. He served his apprenticeship with the firm of Messrs. T. and E. Bush, of Bristol, engineers and chilled-roll manufacturers. In 1861 he entered the drawing office of Messrs. Slaughter and Gruning, of Bristol, afterwards styled the Avonside Engine Co., builders of locomotives, marine engines, stationary engines, and boilers of all kinds. After being a year with that firm, he went to Messrs. Laird Brothers, of Birkenhead, where he was in the drawing office for over two years, then with Mr. Douglas Hebson, of Liverpool, and Messrs. Tod and McGregor, of Glasgow. After a short time with Mr. John Key of Kirkcaldy, he returned in 1866 to the Avonside Engine Co., Bristol, to design their marine-engines and boilers. In 1871 he left them and went back to the firm where he had served his apprenticeship, and entered into partnership with Mr. Thomas S. Bush, a nephew of the previous proprietors, and a former fellow apprentice. The firm was thenceforward styled Bush and de Soyres. They constructed stationary engines for the local rolling mills and other industries, and winding engines for the Bristol and South Wales Collieries. Chilled rolls were a specialty which they supplied not only to firms in this country, but also in France and America. To the West Indies they sent sugar-cane mills and iron barges for the plantations. Mr. de Soyres was taken suddenly ill in the early part of February, and died at his residence at Clifton on 6th March 1902, in his sixty-third year. He became a Member of this Institution in 1877; and was President of the Bristol Association of Engineers in 1900–1901.

CHARLES GRANVILLE VINES was born at Peterborough on 18th February 1873. Having been educated at Rossall School, near Fleetwood, and at the Lincoln School of Science and Art, he was apprenticed to Messrs. Robey and Co., Lincoln. After serving nearly five years with that firm, he went as improver in the outside department of Messrs. Willans and Robinson of Thames Ditton, being afterwards employed for some time at Bankside at the City of London Electric Light Co.'s Works. His health having become impaired, he went to South Africa, where he was engaged in engineering work for the Jumpers Deep and Glen Deep Mines and also other companies. In 1899 he was appointed manager of Mr. Theodore Reunert's electrical works in Kimberley, and local agent for Messrs. Reunert and Lenz, of Johannesburg. He took part in the defence of Kimberley during the siege, and on the completion of the electric light installation he was appointed Borough Electrical Engineer by the Town Council of Kimberley. His death from typhoid fever took place at Kimberley on 28th March 1902, at the age of twenty-nine. He became an Associate Member of this Institution in 1900.

JEROME WHEELOCK was born in Grafton, Mass., United States, on 20th June 1834. Having been educated in the schools of his native town, he served an apprenticeship from 1853 to 1856 at the Taunton Locomotive Works, and was engaged at the same works until 1858 in the drawing office and on general construction work. He then went to Worcester, Mass., where he became manager of the mechanical department of the Washburn Iron Works. While in this position he invented a steam cylinder packing, and commenced its manufacture extensively. On the death of the proprietor of the works in 1867, he carried on the business alone, and then developed other inventions, the most prominent one being the Wheelock automatic steam-engine system, which is largely in use throughout Europe. He received from various Institutes and Exhibitions gold medals and prizes for his steam-engine. In 1888 his business was turned into a company, when he was able to devote more time to his inventions, in connection with which he crossed the Atlantic over sixty times. His death occurred most suddenly. As he was walking along the street in Worcester, he suddenly fell unconscious, and expired in a few minutes from cerebral hemorrhage, on 26th February 1902, in his sixty-eighth year. He became a Member of this Institution in 1898.

INDEX.

1902.

PARTS 1–2.

ABBOTT, R. H., elected Associate Member, 3.

ADAMS, W. J., elected Graduate, 207.

ADAMSON, D., Remarks on Modern Machine Methods, 56.

ADDY, G., Remarks on Standardization of Flanges, 357.

ÅKERLIND, G. F., elected Associate Member, 206.

ALLEN, H. G., elected Associate Member, 206.

ALTERATION OF RULES, President moved alteration to Article 23, 165.—Wicksteed, J. H., Seconded motion, 166. — Hawksley, C., Moved amendment, 166.—Brewster, E. H. G., Seconded amendment, 166.—Chambers, E. J., Remarks on motion, 167.—Stromeyer, C. E., Remarks on motion, 167.—Maw, W. H., Announcement of Special Meeting for confirming Resolution, 168.—Confirmation, 203.

ANDREWS, T., elected Member, 3.

ANNUAL GENERAL MEETING, Business, 137.

ANNUAL REPORT OF COUNCIL, 138. *See* Council, Annual Report.

APRIL MEETING, Business, 295.

ARMISTEAD, T. W., elected Associate Member, 206.

ARNOT, A. J., elected Member, 295.

ASBURY, G. E., elected Member, 295.

ATKINS, E. A., elected Associate Member, 296.

ATKINSON, R. E., *Paper* on Standardization of Flanges, 303.—Remarks on ditto, 341, 367.

AUDITOR, Appointment, 164.

BAILEY, W. D., Memoir, 195.

BAIRD, D. G., elected Member, 206.

BAKER, H., elected Graduate, 297.

BARBER, T. W., Associate Member transferred to Member, 6.

BARTON, G. B., elected Graduate, 297.

BARTRAM, H. A., elected Associate Member, 296.

BEARE, T. H., *Lecture* to Graduates on Gas-Engine Developments, 113.—Remarks on ditto, 135.

BELL, A. M., elected Member, 295.

Bell, F., elected Associate Member, 3.
Bell, R. A., Remarks on Fencing of Machinery, 275.
Bennett, A. E., elected Member, 3.
Berry, F., elected Associate Member, 206.
Bevan, I., elected Associate Member, 296.
Bexon, R. A., elected Graduate, 5.
Blagden, H. R. C., elected Associate Member, 4.
Blenkinsopp, G. J. L., Remarks on Fencing of Machinery, 265.
Boak, W., elected Member, 206.
Bott, W. S., elected Associate Member, 4.
Bow, J., elected Associate Member, 4.
Brewer, R. W. A., elected Associate Member, 296.
Brewster, E. H. G., Remarks on Alteration of Rules, 166.
Briggs, E. R., Remarks on Standardization of Flanges, 359.
Browne, Sir B. C., elected Member, 295.
Bruce, R., Remarks on Modern Machine Methods, 78.
Bryson, J., elected Member, 206.
Burford, H. G., elected Associate Member, 296.
Busfeild, W., elected Associate Member, 4.
Butcher, M. H., Associate Member transferred to Member, 137.
Button, J. W., elected Associate Member, 296.

Carnegie, D., Remarks on Modern Machine Methods, 78:—on Fencing of Machinery, 277.
Carpenter, C. C., elected Member, 3.
Carrick, J. E. C., elected Graduate, 297.
Chabot, V. H., elected Graduate, 5.
Chambers, E. J., Remarks on Modern Machine Methods, 80:—on Alteration of Rules, 167.
Chatwood, A. B., Associate Member transferred to Member, 298.
Clacher, D., elected Member, 3.
Clifford, A. C., elected Graduate, 297.
Clift, C. E., elected Member, 295.
Cloud, J. W., elected Member, 295.
Codd, T. J., elected Associate Member, 206.
Collyer, P. N., elected Associate Member, 4.
Conner, J., elected Member, 3.
Conversazione, 372.
Cook, R. J., elected Member, 295.
Cooper, G., Memoir, 377.
Cooper, J. E., elected Graduate, 6.
Cormack, J. D., elected Member, 3.

Cotsworth, H. G., elected Associate Member, 4.

Cotton Spinning Machinery, Guarding, 221. *See* Guarding of Textile Machinery.

Coueslant, L. D., elected Graduate, 207.

Coulson, H. E., elected Associate Member, 4.

Council, Annual Report, 138.—Number of Members, 138.—Honours, 138.—Deceases, &c., 139.—Financial statement, 140, 146–9.—Research, 141.—Donations to Library, 142, 150–160.—Barrow Summer Meeting, 142.—Meetings, Papers, 142–3.—International Engineering Congress, Glasgow, 143.—Graduates' Meetings, 144.—Award of Graduates' Prizes, 145.—Engineering Standards Committee, 145.—Willans Premium Fund, 150.
  Maw, W. H., Motion for adoption of Report, 160.

Council Appointments, 207.

Council for 1902, 162–3.

Council, Remarks by President on enlargement of Council, 1.

Council, Retiring List, and Nominations for 1902, 2.

Crabtree, J. H., Remarks on Fencing of Machinery, 285.

Cramb, A. C., elected Associate Member, 4.

Crawford, G. W., elected Associate Member, 4.

Crompton, Lt.-Col. R. E., Remarks on Modern Machine Methods, 62.

Dack, W. H., elected Associate Member, 296.

Davey, H., re-elected Member of Council, 162.

Dawbarn, R. P., elected Associate Member, 296.

Dean, W., Remarks on Modern Machine Methods, 102.

Devin, E. H., elected Graduate, 207.

Dewrance, J., Remarks on Standardization of Flanges, 355.

Dinner, Anniversary, 299.

Dixon, J., elected Associate Member, 4.

Dixon, S., Memoir, 195.

Dodridge, A. E., elected Graduate, 6.

Donaldson, H. F., Remarks on Modern Machine Methods, 58.

Donaldson, J., elected Associate Member, 296.

Donkin, B., re-elected Vice-President, 162.—Decease, 205.—Memoir, 378.

Douglas, W. J., Associate Member transferred to Member, 6.

Dryden, W., elected Associate Member, 4.

Dumas, R., Remarks on Modern Machine Methods, 80.

Eaton, G. H., elected Associate Member, 4.

Election, Council, 162.—Members, 3, 206, 295.

Ellington, E. B., appointed Member of Council, 208.

Embleton, C. A., elected Associate Member, 4.

EPPS, L. G. J., elected Associate Member, 4.

ERMEN, G., elected Associate Member, 296.

FEARON, H. C. D., Remarks on Fencing of Machinery, 268.

FENCING OF MACHINERY, *Discussion* on Papers by Messrs. Marshall, Platt, Walker, and Johnson, 248.—Maw, W. H., Variation in practice of factory inspectors, 248.—Hoare, C. C. W., Automatic closing of lift doors, 248; difficulties of factory inspectors, 249; objections to bars for guarding lifts, 250; automatic closing of lift door, 251.—Ireland, W. F., Guarding machine tools, 252; guarding wood-working machinery followed by increased output, 253; fencing circular shafts; low limit of safety, 254; bursting of emery wheels; protection for employers against careless workpeople, 255; rails as guards; number of accidents in factories during 1900, 257.—Robinson, M., Economy derived from guarding, 257; dangers of shop staircases, 258.—Maw, W. H., Additional remarks from W. F. Ireland, 259.—Ireland, W. F., Oiling machinery without removal of guard; guarding "ingoing" side of spur wheels, 259; unsuitability of edge guards for spur wheels, 260; automatic reversing gear for mangles, 261.—Harmer, O., Unsuitability of timber guards, 261; cast-metal most suitable; machinery should be designed with guards, 262; guards to turret lathes and vertical milling-machines, 263.—Halpin, D., Lift accidents, 264.—Blenkinsopp, G. J. L., Great neglect of fencing machine tools, 265.—Orcutt, H. F. L., Guarding ineffectual in Germany, 266; duty of engineers to guard machinery, 267.—Fearon, H. C. D., Riving knives for circular saws; guard to fly-wheel of gas-engines, 268; prevention of lift accidents, 269.—Tebbutt, S., Cap of metal on shaft of steam-engine, 269; reversing motion for machinery; guards for laundry machinery, 270; German system of inspection, 271.—Schönheyder, W., Improved method of starting fly-wheel; movable flap at lift-door and on cage, 272.—Vernon, P. V., Guards on machines should form part of design; objection to wire guards, 273; protection of change wheels of lathes, 274.—Maw, W. H., Guards to printing machinery, 274.—Powrie, W., French and German machines guarded better than English, 275.—Bell, R. A., Guards to be easily removed, 275; saw-guards, 276; turning gear for engines, 277.—Carnegie, D., Dangers arising from faulty guards, 277; from chips flying into men's eyes, 278.—Stevens, E. C., Lift accidents, 278.—Winston, H. H., Safety device for lifts, 280.—Harmsworth, H., Danger in self-closing doors, 280; Board of Trade inspection of passenger lifts; accidents arising from carelessness, 281.—Storey, A.W., Projecting stud on revolving shaft; cast-iron versus wire-work guards, 282; advantage of removable guards, 283; safety starting-handle and guard for gas-engine, 284.—Maw, W. H., Good results arising from discussion, 285.—Hoare, C. C. W., Thanks of Factory Inspectors, 285.—Maw, W. H., Value of discussion, 285.—Crabtree, J. H., Guards to gas- and steam-engines, 285; to textile machinery, 286; to machine tools, 287.—Parkinson, E., Lathe protection, 288; conditions required in guards, 289.—Seymour, W. F. E., Constant inspection of guards required; accidents from machinery from 1895 to 1900; objection to rail-guarding of steam- and gas-engines, 291.—Platt, S. R., Increase of guards decreases efficiency of production; guarding machines for home and abroad, 292.—Walker, H. C., Locking gear for lifts, 293; bar in cage of lifts, 293.

FENCING OF STEAM- AND GAS-ENGINES, *Paper* by H. D. Marshall, 211.—Arrangement of works, 211.—Guard rail to horizontal compound engine, 212.—Lubrication of crosshead pin, 213.—Double rail-guard with wire netting, 214.—Turning gear, 215.—Safety lubricator for wall-box bearing, 217.—Types of engines; guard for shaft end, 218.—Guard for vertical engines; for portable engines; for winding engines, 219; for traction engines, 220.—Precautions to be taken in starting steam-engines, 220. (*For Discussion, see* FENCING OF MACHINERY.)

FINLAYSON, R. W., elected Member, 3.

FITZMAURICE, M., elected Member, 295.

FLANGES, Standardization, 303. *See* Standardization of Flanges.

FOGGO, W., elected Member, 3.

FORGAN, C., elected Associate Member, 296.

FOSTER, R. J., elected Graduate, 297.

FOSTER, S., elected Associate Member, 4.

FRANKAU, G. N., elected Graduate, 297.

FRANKLIN, E. S., elected Member, 206.

FUNNELL, H. N., elected Graduate, 207.

FURNESS, C., Associate Member transferred to Member, 6.

GARNETT, H., elected Associate Member, 296.

GAS-ENGINE DEVELOPMENTS, *Lecture* by T. H. Beare to the Graduates, 113.—Society of Arts trials in 1888; engines tested, 113; Crossley engine with lift-valves; temperature of exhaust gases and quantity of air admitted, 114; results obtained, 115.—Otto cycle; scavenging in Griffin engine, 116; in Crossley engine, 117.—Tests in 1894, showing economy, 118; —Gas producers, 118; Dowson gas, 119; Mond gas, 120; analysis of Mond gas, 121.—Koerting two-cycle 350-B.H.P. engine; working cycle, 122; methods of test, 123.—Test of 400-H.P. Crossley engine; of 500-H.P. "Premier" gas-engine, 124.—Use of blast-furnace waste gases, 125; "Simplex" gas-engine, 126; tests, 127; removal of dust from blast-furnace gas, 129; analyses of same gas, 131.—Westinghouse engines with natural gas, 132.—Freedom of gas-engines from breakdown, 133.—Reports of Gas-Engine Research Committee, 134.

Kennedy, A. B. W., Society of Arts trials and size of engines; vote of thanks to lecturer, 135.—Beare, T. H., Acknowledgment of vote, 135.—Stevens, P. H., Thanks to Chairman, 136.

GAS-ENGINES, FENCING, 211. *See* Fencing of Steam- and Gas-Engines.

GEBBIE, J., elected Member, 3.

GEORGE, A. J., elected Graduate, 6.

GEORGE, J. W., elected Associate Member, 4.

GIBBS, G. J., elected Member, 206.

GLEDHILL, A. H., elected Associate Member, 296.

GOLLEDGE, W. T., elected Associate Member, 4.

GOUDIE, W. J., elected Associate Member, 4.

GRADUATES' PRIZES, Presentation, 161.

GREAVES, W., elected Member, 3.

GREGORY, H. G., elected Graduate, 207.

GRIERSON, H. F., elected Associate, 207.

GUARDING MACHINE TOOLS, *Paper* by W. H. Johnson, 241.—Materials for guards; conditions for perfect guard, 241.—Spur-wheel guard on milling machine, 242.—Timber guards; cast-iron guards, 243; sheet-metal guards, 244; hoops, etc., for guards; wire-work guards, 245; unsuitable wire-work guard; difficulty of fencing change wheels, 246; guarding feed mechanism of capstan lathe, 247. (*For Discussion, see* FENCING of MACHINERY.)

GUARDING OF MACHINERY, 211, 221, 231, 241.

GUARDING OF TEXTILE MACHINERY, *Paper* on Fencing or Guarding Machinery used in Textile Factories, with special reference to machinery used by Cotton Spinners and Manufacturers, by S. R. Platt, 221.—Advantage of hinged guards, 221.—Work-people not in favour of guards; stringent factory laws in Russia, 222.—Protection needed against careless work-people; guards for bale breaker and exhaust opener, 223; for opener and scutcher, 224; guarding calender roller wheels, and carding engine, 225; guards for slubbing and roving frames; difficulty of guarding self-acting mule, 227; guards to looms, 228. (*For Discussion, see* FENCING OF MACHINERY.)

HAARER, E. Du C., elected Member, 3.

HAINES, C. J., Associate Member transferred to Member, 6.

HALE, H., elected Associate Member, 4.

HALER, P. J., elected Associate Member, 4.

HALL, J. E., elected Associate Member, 206.

HALPIN, D., Remarks on Fencing of Machinery, 264.

HAMILTON, Lord G., Remarks at Institution Dinner, 301.

Hamilton, G. J., elected Graduate, 297.

Hancock. P. B., elected Graduate, 297.

Hardcastle, E., elected Associate Member, 4.

Hardy, J. H., elected Associate Member, 4.

Harmer, O., Remarks on Fencing of Machinery, 261.

Harmsworth, H., Remarks on Fencing of Machinery, 280.

Harper, N. C. T., elected Associate Member, 4.

Harris, W., elected Member, 3.

Haste, F. C., elected Associate Member, 206.

Haswell, F. J., elected Member, 3.

Hatch, W. T., Remarks on Standardization of Flanges, 351.

Hatfield, K. G. S., elected Graduate, 6.

Hathorn, J. C. M., elected Associate Member, 4.

Hatton, R. A., elected Graduate, 6.

Hawksley, C., Remarks on Alteration of Rules, 166.

Hawksley, C. W., elected Associate Member, 4.

Hayashi, Viscount, Remarks at Institution Dinner, 301.

Hayward, G., elected Graduate, 6.

Hayward, T. W. A., elected Member, 3.

Heald, H., elected Graduate, 6.

Heard, F. G., elected Graduate, 6.

Hemingway, R. L., elected Associate Member, 296.

Henderson, D. D., elected Associate Member, 4.

Hewett, J. R., elected Graduate, 207.

Hignett, A. H., elected Member, 3.

Hill, A. J., Remarks on Modern Machine Methods, 79.

Hinchliffe, G. W., elected Associate Member, 206.

Hincks, J. M., elected Associate Member, 4.

Hitchins, C. F., Associate Member transferred to Member, 6.

Hoare, C. C. W., Remarks on Fencing of Machinery, 248, 285.

Hobbs, C. J., *Paper* on Triple-Expansion Steam-Engine Trial, 171.

Hodgson, R. B., Remarks on Modern Machine Methods, 106.

Holden, E. C., elected Associate Member, 4.

Holden, R., Memoir, 196.

Holland, B. A., elected Associate Member, 4.

Honiball, C. R., Associate Member transferred to Member, 6.

Hopkinson, J., Memoir, 381.

Hoyte, P. S., elected Associate Member, 296.

Hulley, R. D., elected Member, 206.

Hunt, F., elected Associate Member. 4.

Hunter. C. L., Memoir, 197.

Hutchinson, W. L., elected Graduate. 297.

Hyde, G., elected Associate Member, 206.
Hydraulic Pumping Engine, Triple-Expansion, 169. *See* Triple-Expansion Steam-Engine Trial.

Inchley, W., elected Graduate, 6.
Incledon, W. B., Remarks on Standardization of Flanges, 348.
Institution Dinner, 299.
Ireland, W. F., Remarks on Fencing of Machinery, 252, 259.
Izod, E. G., elected Associate Member, 296.

Jarvis, R., elected Associate Member, 4.
Jeffreys, J., elected Member, 206.
Jepson, G. F., elected Graduate, 297.
Jepson, J. T., elected Member, 206.
Johnson, F. A., elected Associate Member, 4.
Johnson, W. H., *Paper* on Guarding Machine Tools, 241.
Johnston, L., elected Associate Member, 4.
Jones, T. M., elected Associate Member, 296.
Jukes, J. W., elected Associate Member, 4.

Keable, A. H., elected Associate Member, 4.
Kennedy, A. B. W., Remarks on Gas-Engine Developments, 135, 136.
Kenshole, H. H., elected Associate Member, 206.
Kentish, H., elected Associate Member, 297.
Kilroy, W. D., elected Associate Member, 297.
King, H. J. H., elected Associate Member, 4.
Kirlew, R. L., Jun., elected Graduate, 6.
Kitching, H. W., R.N., elected Member, 295.
Kitsell, A. E., elected Associate Member, 297.

Lampard, P., elected Associate Member, 5.
Lazenby, A., elected Member, 295.
Lea, H., appointed Member of Council, 208.
Lewenz, H. I., elected Associate Member, 5.
Lewis, H. W., Memoir, 383.
Lewis, Sir W. T., Bart., re-elected Member of Council, 162.
Lift-Shafts, Protection, 231. *See* Protection of Lifts.
Linscott, A. B., elected Associate Member, 297.
Lloyd and Lloyd, *Appendix* to Paper on Standardization of Flanges, 339.
Longbottom, L., Memoir, 198.
Loscher, A. P., elected Associate Member, 206.
Lukis, W. R. F., elected Member, 3.
Lupton, N. D., elected Associate Member, 5

Machine Methods, Modern, 9. *See* Modern Machine Methods.

Machine Tools, Guarding, 241. *See* Guarding Machine Tools.

Machinery, Fencing and Guarding, 211, 221, 231, 241.

Mackenzie, T. B., Graduate transferred to Member, 137.

Macnab, T. P., elected Associate Member, 5.

MacNay, A., elected Member, 295.

Mansergh, J., appointed Member of Council, 208.

March Meeting, Business, 205.

Marsden, A., elected Associate Member, 5.

Marshall, F. H., Remarks on Standardization of Flanges, 362.

Marshall, H. D., *Paper* on Fencing of Steam- and Gas-Engines, 211.

Martin, E. P., re-elected Vice-President, 162.

Mascall, A. E., elected Associate Member, 5.

Mason, C. L., elected Graduate, 6.

Mathot, R., elected Member, 295.

Matsubara, T., elected Associate Member, 297.

Maw, W. H., Remarks on enlargement of Council, 1:—on Modern Machine Methods, 47, 81, 101.—Moved adoption of Annual Report, 160.—Presentation of Graduates' Prizes, 161.—Re-elected President, 162.—Remarks on re-election as President, 164:—on Alteration of Rules, 165, 166, 168:—on decease of Mr. Bryan Donkin, 205:—on Council Appointments, 207:—on Fencing of Machinery, 248, 259, 274, 285:—at Institution Dinner, 300, 301:—on Standardization of Flanges, 340.

Mayo, C. R., elected Associate Member, 206.

McDougall, H., elected Associate Member, 297.

McGhee, A., elected Associate Member, 5.

McLean, R. A., re-appointed to audit Institution accounts, 164.

McTaggart, J., Memoir, 198.

Meetings, 1902, January, 1:—Extra, 8.—Annual General, 137.—Special, 165 203.—March, 205.—Extra, 209.—April, 295.

Memoirs of Members recently deceased, 195, 377.

Mensforth, H., elected Associate Member, 5.

Mirrors for Search Lights, Notes on Turning, 373. *See* Turning Mirrors for Search Lights.

Mitchell, J., elected Associate Member, 297.

Modern Machine Methods, *Paper* by H. F. L. Orcutt, 9.—Accuracy and cheapness of product desired, 9.—Gauges, 10; limit gauges, 11; table of internal and external limit gauges, 13.—Light milling, 14; essentials in economical milling, 15; vertical milling machine, 15; circular mill, 16.—Heavy milling, 16.—Planing; quick return stroke, 17; electric chucks; magnetic-clutch driving mechanism, 18.—Grinding, 19; surface grinders, 20; cylindrical grinding, 21.—Chucking, 21; tools used in chucking machines, 22.—Turning, 24; tool speeds for cutting soft steel, 26; latest practice in lathe-work, 27.—Polishing, 27.—Gear cutting, 28.—Turret machines, 28; advantages of modern turret machines, 29.—Vertical boring mill, 29.—Drilling and jig work, 30.—Portable machines; advantages, 32; section of large floor-plate, 33.—Small tools; cutters, reamers, taps, dies, arbors, &c., 34.—Tool-Room, 36.—Erecting department, 37.—Testing and analysing material, 38.—Shop fittings, 39.—Chemical composition of light iron castings, 40.—Organization, 41.—Extensive application of modern methods possible, 43.—Apprenticeship question, 44.

Discussion.—Maw, W. H., Thanks to author, 47.—Orcutt, H. F. L., Large scope for discussion, 48.—Wicksteed, J. H., Saving effected by heavy milling, 48; milling and planing, 49; double-cutting tool boxes for planing machine, 51.—Rowan, J., Work effected by planing machine, 52; advantages of boring mill over facing lathe, 53; standardization of work, 54; apprenticeship question; deficiencies of British workshops, 55.—Adamson, D., Grinding spindles in Lancashire, 56; turret lathes in textile machinery works, 57.—Donaldson, H. F., Vastness of subject, 58; limit-gauges in grinding work; softness of metal in American machines, 59; re-organization of workshops; tool-rooms, 60; education of apprentices, 61.—Thornycroft, J. I., Variety of work in shops, 62.—Crompton, Lt.-Col., R. E., Advantages of limit gauges, 62; use of tool rooms, 63; construction of armatures; lighting of workshops, 64; over-capitalization of German workshops, 65.—Weir, W., Progress in modern workshops, 66; lighting and cleanliness; shop railways, 67; vertical boring mill, 68; horizontal drilling machine, 69; moderation in modernity, 70.—Richardson, J. R., English and American methods, 70; adoption of milling machines, 71; moulding machines, 72; accuracy of jigs and limit gauges, 73.—Ransome, L. H., Speed of machine tools, 74; speed of planing machines; economy effected in grinding, 75; advantage of tool-rooms, 76; analysis of materials, 77.—Bruce, R., Increasing adoption of modern methods, 78.—Carnegie, D., Limit gauges used by unskilled men; saving effected by milling tools, 78.—Hill, A. J., Two speeds for planing machines; one man working six milling machines, 79.—Dumas, R., Planing cast-iron at 38 feet per minute, 80.—Chambers, E. J., Competition of departments in works, 80.—Wright, F. G., Apprenticeship question, 81.—Maw, W. H., Grinding at Swindon Works, 81.—Wright, F. G., Grinding machinery for finishing off rough forgings, 82.—Riches, T. H., Grinding machinery at Taff Vale Railway Works, 82; duplicate work in smiths' shop; stamping; grinding to standards, 83.—Orcutt, H. F. L., American and English methods, 83; milling versus planing machines, 84; speed of milling machines, 85; accurate cost-keeping; boring mill versus face lathe; elaborate fittings, 86; heating and lighting of workshops; 50 men under one foreman, 88; grinding instead of turning cylindrical parts; reduction of number of gauges, 89; apprenticeship question; shop managers' narrow ideas, 90; spindle grinding: turret lathes; forging versus grinding, 91; economy of limit gauges; soft material; necessity of laboratory, 92; advantage of tool-room; apprenticeship question, 93; viewing department, 95; heavy and light manufacturing trades, 96; advantages of good floor, proper ventilation and light, 97; American work just "good enough," 98; speeds of machines; tool-rooms and tool-stores, 99; smith shop versus machine shop, 100; classification of British engineering work, 101.—Maw, W. H., Thanks to author, 101.—Dean, W., Grinding machines at Swindon, 102; slide-bar grinder; piston-rod grinder, 102: cutting tools, 103; lapping machines; disc surface grinder, 104: piston-valve grinding, 105; disc-grinding machine, 106.—Hodgson, R. B., Gauges; grinding, polishing, 107; drilling and jig work, 108; small tools; tool-room, 109; apprenticeship question, 110.—Schönheyder, W., Chucking, 111; screw-machine, 112.

Monks, F. W., elected Member, 295.

Montague, G., elected Graduate, 207.

Moore, T. R., elected Associate Member, 5.

Morgan, H. F. S., elected Graduate, 6.

Morris, C. C. B., elected Graduate, 6.

Mortimore, W., elected Member, 3.

Muckley, W. H., elected Member, 3.

Muggeridge, H. C., elected Associate Member, 297.

Muir, A., Memoir, 384.

Munn, J. A., Memoir, 199.

Munyard, A. W., elected Graduate, 6.

Murphy, W., elected Associate Member, 206.

Musgrave, F. E., elected Member, 296.

Nesbit, D. M., Remarks on Standardization of Flanges, 347.

Newbigging, J., elected Associate Member, 5.

Newman, W. E., elected Member, 296.

Newman, W. H., elected Associate Member, 5.

Nicholson, E., elected Graduate, 207.

Nixon, C. B., elected Associate Member, 206.

Noakes, T. E., elected Member, 296.

O'Connell, J. G., elected Associate Member, 297.

Oldbury, A., elected Member, 296.

Orcutt, H. F. L., *Paper* on Modern Machine Methods, 9.—Remarks on ditto, 48, 83:—on Fencing of Machinery, 266.

Orr, T. R. J., elected Associate Member, 206.

PAPWORTH, J. W., elected Associate Member, 297.

PARKINSON, E., Remarks on Fencing of Machinery, 288.

PARRATT, H. E., elected Graduate, 207.

PAUL, S. F., elected Graduate, 297.

PENN, B. H., elected Graduate, 207.

PETTIT, A. E., elected Associate Member, 5.—*Paper* on Turning Mirrors for Search Lights, 373.

PHILPOT, H. P., elected Associate Member, 5.

PIMM, A. W., elected Graduate, 297.

PIRRIE, Rt. Hon. W. J., re-elected Member of Council, 162.

PITTAR, A. V., elected Associate Member, 297.

PLATT, S. R., *Paper* on Guarding of Textile Machinery, 221.—Remarks on ditto, 292.

POOLE, R., elected Associate Member, 297.

POWELL, H., elected Graduate, 297.

POWRIE, W., Remarks on Fencing of Machinery, 275.

PRESCOTT, W. H., elected Member, 3.

PRITCHARD, W. E., elected Associate Member, 206.

PROTECTION OF LIFTS, *Paper* on Protection of Lift-Shafts, and Safety Devices in connection with Lift-Doors and Controlling Gear, by H. C. Walker, 231.—Fewness of lift accidents, 231.—Sliding shutter; danger of automatically-closing doors, 232; locking of starting rope; method of guarding lift with attendant in cage, 233.—Requirements for safety of lift openings; mechanical and power appliances, 235: automatic lift gates, 236; automatic gate arrangement for goods hoists; Hollins-Amendt locking gear, 237; hydraulic semaphore safety arms for lifts; electrically controlled shutter, 238.—Electric lifts worked on push-button system, 240. (*For Discussion, see* FENCING OF MACHINERY.)

PULVERTAFT, R. G., elected Associate Member, 297.

RADLEY, W. J. P., elected Graduate, 207.

RANSOME, L. H., Remarks on Modern Machine Methods, 74.

REEVE, E., elected Graduate, 207.

REID, J. W., elected Associate Member, 5.

REPORT OF COUNCIL, ANNUAL, 138. *See* Council, Annual Report.

RICHARDSON, J. R., Remarks on Modern Machine Methods, 70.

RICHARDSON, Sir T., re-elected Member of Council, 162.

RICHES, T. H., Remarks on Modern Machine Methods, 82.

RITCHIE, A. M., elected Associate Member, 206.

ROBINS, A. G., elected Member, 296.

ROBINSON, J. F., appointed Member of Council, 208.

ROBINSON, M. H., elected Member of Council, 162.—Remarks on Fencing of Machinery, 257.

ROGERSON, T. B., elected Member. 296.

ROSS, J.. elected Member, 3.

ROUNTHWAITE, H. M., Seconded motion for re-appointment of Auditor. 164.—Remarks on Standardization of Flanges, 365.

ROWAN, J., Remarks on Modern Machine Methods. 51.

ROWE, A., Memoir, 200.

RULES, ALTERATION, 165, 203. *See* Alteration of Rules.

RUTHVEN-MURRAY, E. T., elected Member, 296.

RUTTER, H. F., elected Member, 296.

SAINTY, C., elected Member, 3.

SANDFORD, J., elected Associate Member, 5.

SAVAGE, J. T., elected Member, 206.

SAYERS, R. J. H., elected Member, 296.

SCHÖNHEYDER, W., Remarks on Modern Machine Methods, 111 :—on Fencing of Machinery, 272.

SCHONTHEIL, T., elected Associate Member, 5.

SCOTT, H., elected Associate Member, 5.

SEARCH LIGHTS, Turning Mirrors for, 373. *See* Turning Mirrors for Search Lights.

SEYMOUR, W. F. E., Remarks on Fencing of Machinery, 290.

SHARMAN, P. A., elected Member, 3.

SHAWCROSS, G. N., Associate Member transferred to Member, 298.

SHAWFIELD, C. E. C., elected Member, 296.

SHIMMIN, G. F., elected Graduate, 207.

SLATER, J. G., elected Member, 206.

SMAIL, C. G., elected Associate Member, 5.

SMITH, E. E., elected Graduate, 207.

SMITH, H. L., elected Associate Member, 5.

SMITH, W. T., elected Associate Member, 206.

SOYRES, F. J. de, Memoir, 385.

SPEAR, C. O., elected Graduate, 207.

SPECIAL MEETINGS, 165, 203.

SPENCER, J. W., appointed Member of Council, 208.

STANDARDIZATION OF FLANGES, *Paper* by R. E. Atkinson, 303.—Benefits of standardization, 303; desire of engineers for uniform standard; previous reports on standardization in America, 304; and in Germany; practice in France and Great Britain, 305.—Flanges adopted by American Society of Mechanical Engineers, 306.—Flanges adopted in America in 1902, 307.—Flanges adopted by Association of German Engineers, 308.—Standard flanges adopted by Hopkinson and Co. and Dewrance and Co., 310; by Mather and Platt, 311; by Russell and Sons, 312.—Bolt-holes; lack of uniformity in German flanges, 313.—Standard proposed by Schäffer and Budenberg, 315.—Flanges adopted by author's firm, 317–9.—Interchangeability of bolts. 320: diagrams showing position of bolt-holes, 322.—Tension tests of bolts, 324.—Comparison of author's standard with others in use, 326.—Cast-iron and cast-steel flanged fittings, 328; proposed standard, 329.—Diagrams of proposed flanged connections, 330–3.—Principles adopted in determining standard, 334.—Arrangement of bends, 335.—Flanges used by Chicago Crane Co., 337.—Summary of replies by leading firms as to adoption of standard flanges, 339.

Discussion.—Maw, W. H., Thanks to author, 340; appointment of Committee to consider subject, 340.—Atkinson, R. E., Standardization of flanges and of machine parts, 341.—Stromeyer, C. E., Standardization of locomotives and threads of screws, 342; clearance in bolt-holes, 343; pitch of bolts, 344; drilling bolt-holes, 345; objections to standardizing holes, 346.—Nesbit, D. M., Importance of stock question, 347; jointing material; weakness of metal caused by increased number of holes, 348.—Incledon, W. B., Commercial aspect of the question, 349; bolts in multiplies of four, 350.—Hatch, W. T., Consumers' point of view; objection to interchangeability of high-pressure and low-pressure fittings, 351; size of pitch, 352; range of standards, 353; drilling bolt-holes, 354; objection to large stock of undrilled fittings, 355.—Dewrance, J., Difficulty of adopting standard, 355; jointing, 356.—Addy, G., Specifications of borough engineers, 357: machine for drilling pipe-holes, 358.—Briggs, E. R., Objection to author's standard, 359; stress on bolts, 360; distance of centre of bolt to edge of flange, 361.—Marshall, F. H., Standards adopted by Wilsons, Pease and Co., 362.—Rounthwaite, H. M., Standards for marine work; formula for finding pressures, 365; thickness of pipe-flanges, and pitch of bolts, 366; different standards for different pressures, 367.—Atkinson, R. E., Origin of author's standard, 367; excessive diameter of American flanges, 368; uniformity in distances from centre of bolt to edge of flange; breakdowns, 369; multiples of four for bolts; danger of fixing low-pressure instead of high-pressure fittings, 370; copper and brass fittings, 371.

STARLEY, R., elected Associate Member, 5.

STEAM- AND GAS-ENGINES, Fencing, 211. *See* Fencing of Steam- and Gas-Engines.

STEAM-ENGINE TRIAL, Triple-Expansion, 169. *See* Triple-Expansion Steam-Engine Trial.

STEED, A. W., elected Graduate, 6.

STENNING, H. W., elected Associate Member, 5.

STEVENS, E. C., Remarks on Fencing of Machinery, 278.

STEVENS, P. H., Thanks to Chairman of Graduates' Meeting, 136.

STEVENSON, E. J., elected Graduate, 297.

Stevenson, J., elected Associate Member, 297.
Stirling, J. M., elected Associate Member, 5.
Stodola, A., elected Member, 296.
Storey, A. W., Remarks on Fencing of Machinery, 282.
Stow, G., elected Associate Member, 206.
Stromeyer, C. E., Motion for re-appointment of Auditor, 164.—Remarks on Alteration of Rules, 167; on Standardization of Flanges, 342.
Sumner, L., elected Associate Member, 5.
Swan, H. A., elected Graduate, 298.

Talbot, E., elected Graduate, 6.
Tannett-Walker, A., appointed Vice-President, 207.
Taylor, F. C., elected Associate Member, 297.
Taylor, J., Memoir, 201.
Taylor, W., elected Associate Member, 297.
Tebbutt, S., Remarks on Fencing of Machinery, 269.
Textile Machinery, Guarding, 221. *See* Guarding of Textile Machinery.
Thornycroft, J. I., Remarks on Modern Machine Methods, 62.
Threlfall, G., Associate Member transferred to Member, 298.
Ticehurst, H. G., Associate Member transferred to Member, 6.
Tools, Guarding, 241. *See* Guarding Machine Tools.
Townend, S., elected Associate Member, 5.
Transferences of Associate Members, etc., 6, 137, 298.
Travis, E., elected Associate Member, 5.
Triple-Expansion Steam-Engine Trial, *Paper* by C. J. Hobbs, 169.—Object of trials, 169.—Description of engine; indicator diagrams, 170.—Water Pumps; Boilers, 174.—Superheater; Coal, 175.—Feed-measuring tanks, 176.—Contract requirements, 177.—Heat Balance Sheets, 178.—Thermal efficiency, 179.—Summary of observations, 184–193.
Tubbs, W. E., elected Associate Member, 297.
Tulip, W., elected Graduate, 298.
Turning Mirrors for Search Lights, *Paper* by A. E. Pettit, 373.—Glass Mirrors shattered by shots in Boer War; difficulties attending construction of metal-faced mirrors, 373; description of construction, 374.—Intensity of light compared with that of glass mirrors, 374; effects of rifle shot, 375.
Turpin, W. A., elected Associate Member, 5.
Tweedy, J., appointed Member of Council, 208.

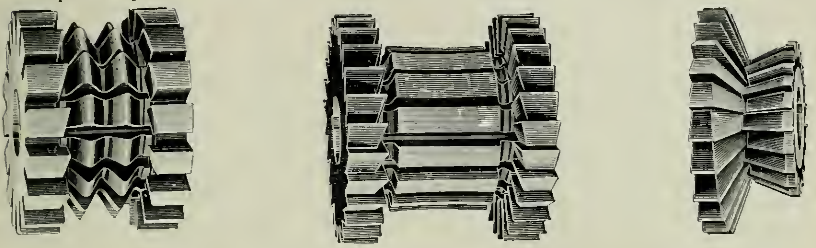
Urie, J. B., elected Associate Member, 297.

Vernon, H., elected Associate Member, 207.
Vernon, P. V., Remarks on Fencing of Machinery, 273.
Vines, C G., Memoir, 386.

Wade, F. R., elected Associate Member. 5.
Wainford, R. H., elected Member. 296.
Walker, H. C., *Paper* on Protection of Lifts, 231.—Remarks on ditto, 293.
Walker, P., elected Member. 3.
Wallace, J. C., elected Member. 3.
Ward, S. A., elected Member, 3.
Watkinson, F. G., elected Member, 296.
Watts, P., elected Member. 296.
Wayte, J. B., elected Associate Member. 207.
Webster, A. G., elected Graduate, 298.
Weir, W., Remarks on Modern Machine Methods. 66.
West, H. H., appointed Member of Council, 208.
West, W. P., elected Associate Member, 5.
Westacott, P., elected Graduate, 298.
Westgarth, T., elected Member. 296.
Weston, W. N., elected Associate Member. 297.
Wheelock, J., Memoir. 387.
Whichello, R. E., elected Associate Member. 5.
Whitelock, W. H., elected Associate Member. 5.
Whittaker, F. W., elected Member, 3.
Whittingham, P., elected Graduate, 6.
Whittington-Cooper, A., elected Graduate, 207.
Wicksteed, J. H., Remarks on Modern Machine Methods. 48:—on Alteration of Rules, 166.
Wilkinson, F. A., elected Associate Member, 207.
Wingate-Saul, A. W., elected Associate Member, 5.
Winstanley-Wallis, T. M., elected Associate Member, 5.
Winston, H. H., Remarks on Fencing of Machinery, 280.
Wolff, C., elected Associate Member, 297.
Wolstenholme, W., elected Graduate, 6.
Wood, C. C., elected Graduate, 6.
Wood, H. A., elected Member, 3.
Woodeson, W. A., elected Associate Member, 207.
Wright, F. G., Remarks on Modern Machine Methods, 81, 82.
Wyles, D. D., elected Member, 296.
Wyllie, J., elected Member, 296.

Yerbury, H. E., elected Associate Member, 207.
York, R. L., elected Graduate, 6.
Young, G. S., Memoir, 201.

Fig. 4. *Built-up Formed Cutters for Circular Milling.*



Rope Pulleys. Belt Pulleys. Bevel Wheels.

Fig. 5. *Circular Milling Machine at work.*

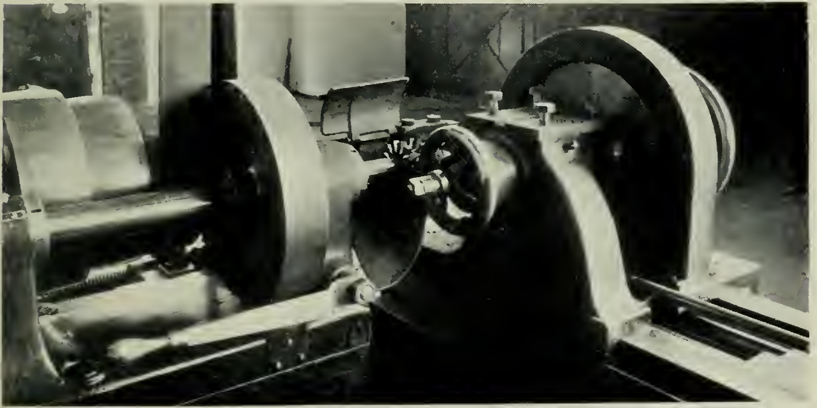


Fig. 6. *Samples of Circular Milling work.*

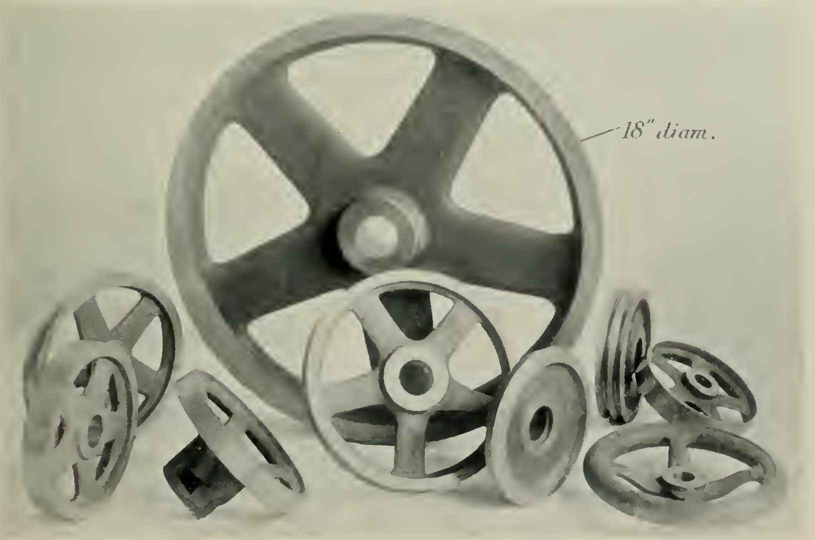


Fig. 7. *Milling a Lathe Bed.*

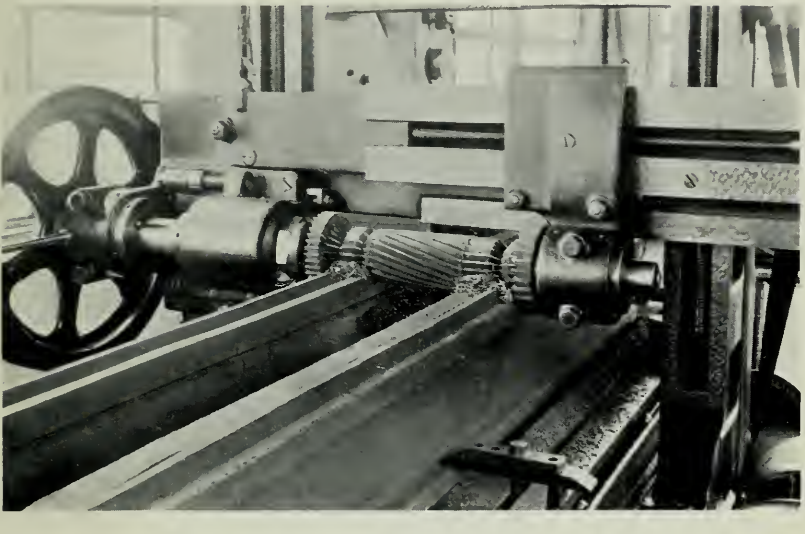


Fig. 8. *Template used in planing a Lathe Bed.*

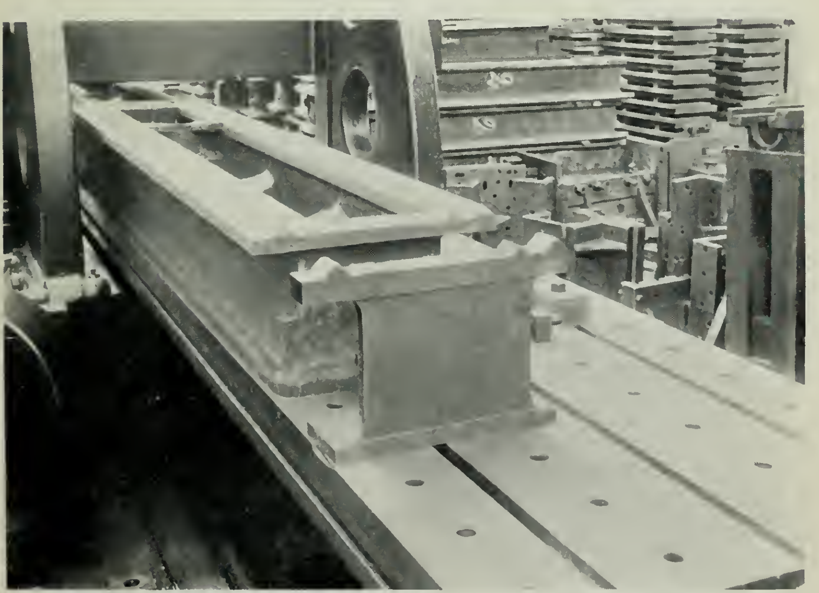


Fig. 11. *Vertical Chucking Machine.*

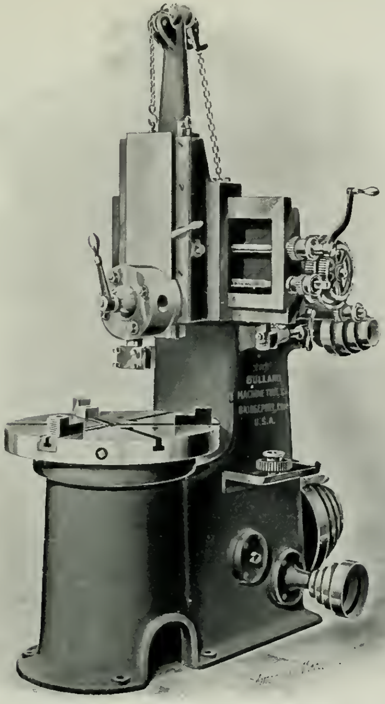


Fig. 12. *Horizontal Chucking Machine.*

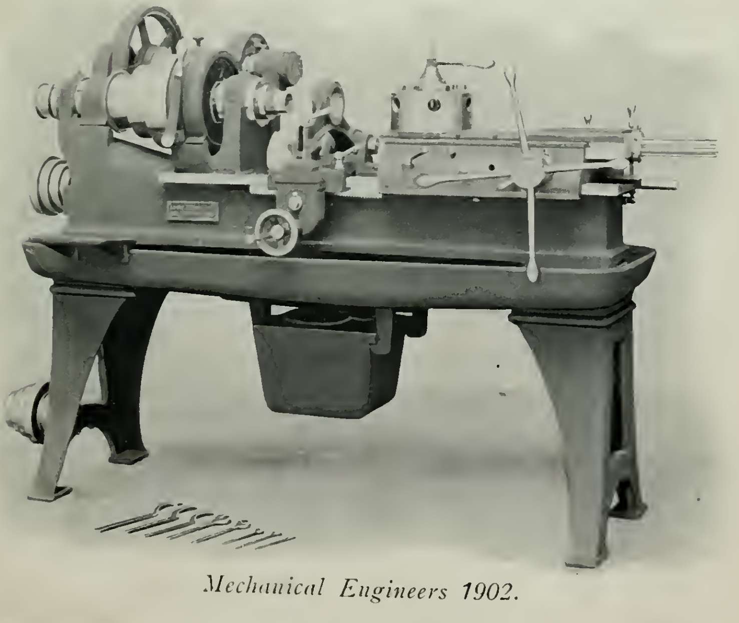
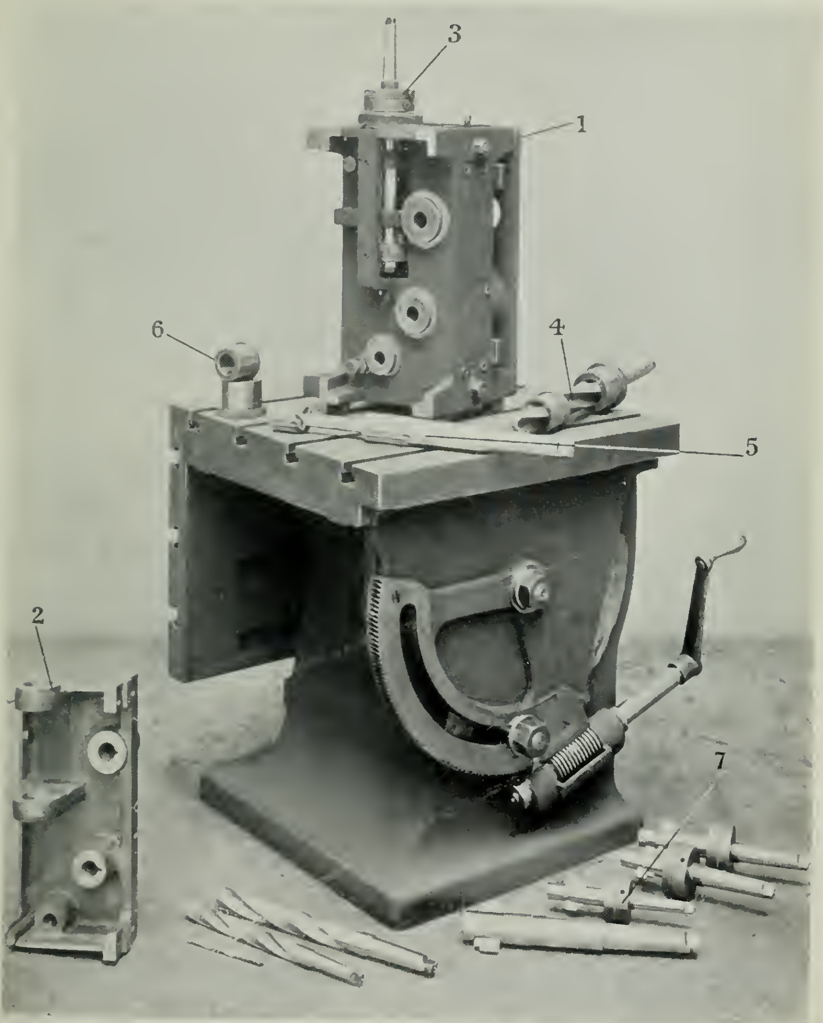


Fig. 14. *Jig, with tools and work.*



1. Jig. 2. Part to be jigged.
3. Boring Tool, with stop collars in place in jig.
4. Boring Tool and two Guide Bushes.
5. Double Reamer for finishing two holes of different diameters.
6. Extra hardened and ground Guide Bushes.
7. Facing Tools, with adjustable stop collars for regulating depth of cut.

Shop Features.

Fig. 17. *Tool Stand.*

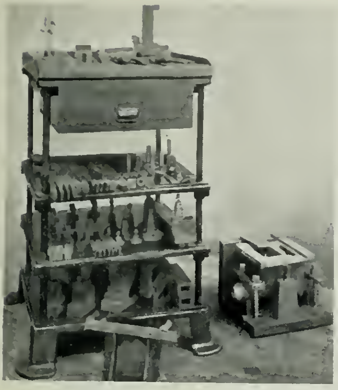


Fig. 18. *Fitter's Bench.*

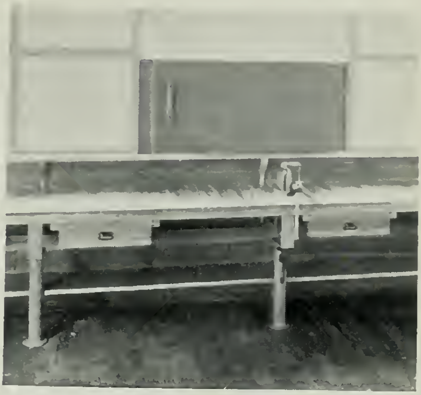


Fig. 19. *Bolt Rack.*

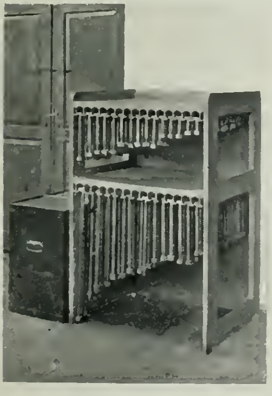


Fig. 20. *Shop Flooring.*

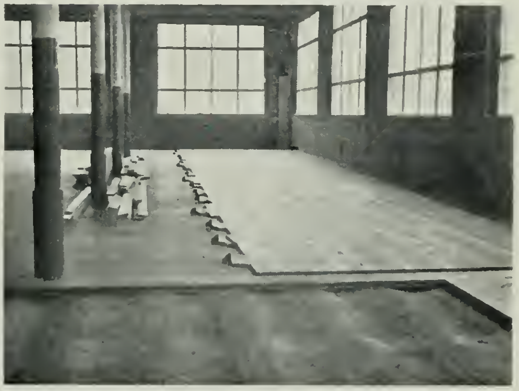


Fig. 21.
School for Apprentices.

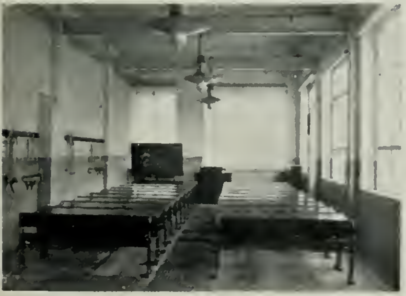
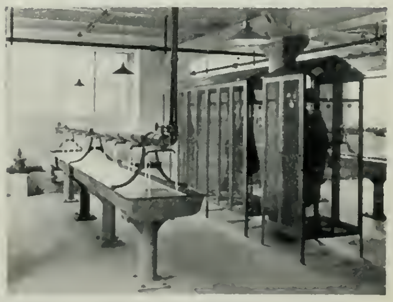


Fig. 22.
Lockers and Washstands.



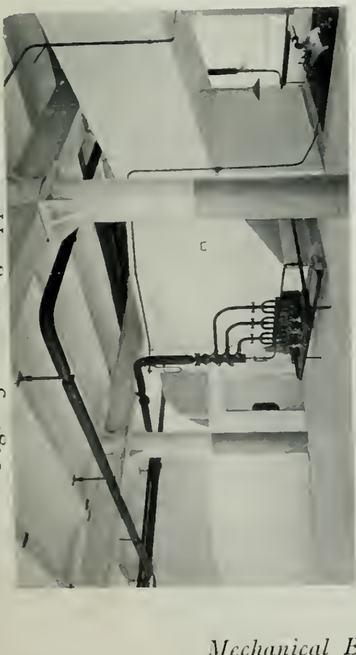


Fig. 23. *Machine Shop. Heating Apparatus.*

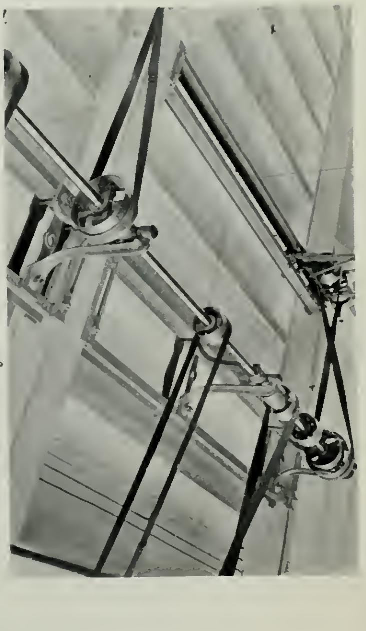


Fig. 24. *Ceiling arranged for easily putting up Main Shaft and Counter Shafts.*

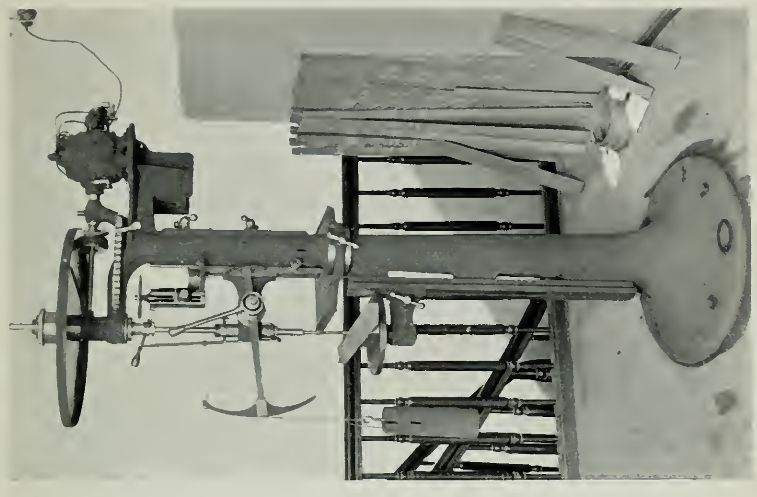


Fig. 25. *Drilling Machine for testing the hardness of iron, and record card to go with same.*

Samples of Gauges, Boring Tools, and Circular Milling exhibited at Meeting.

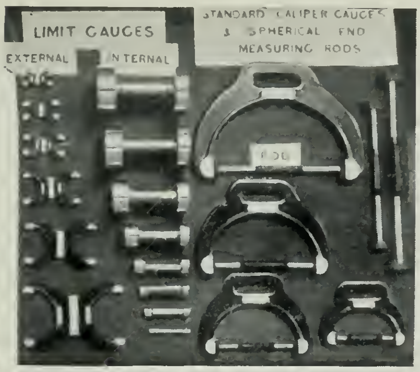


Fig. 26. *Limit and Caliper Gauges.*

Fig. 27. *Boring and Drilling Tools with Jig.*

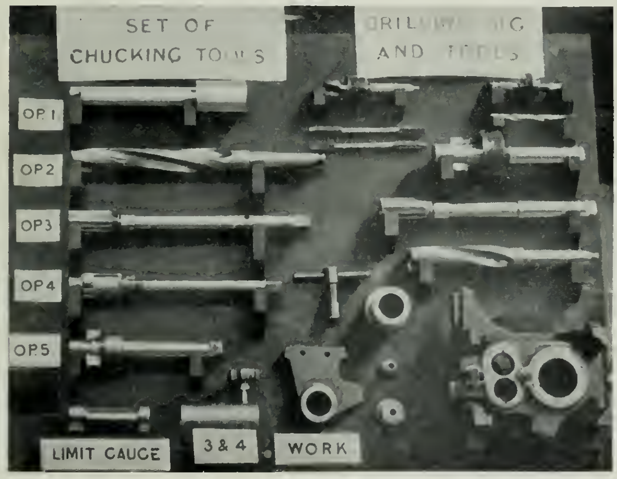
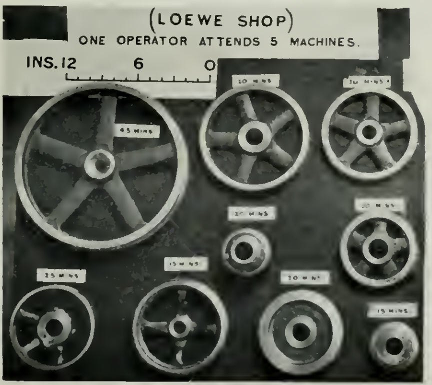


Fig. 28. *Circular-Milled Work.*



Samples of Grinding Work exhibited at Meeting.

Fig. 29. *Steel Spindles, etc.*

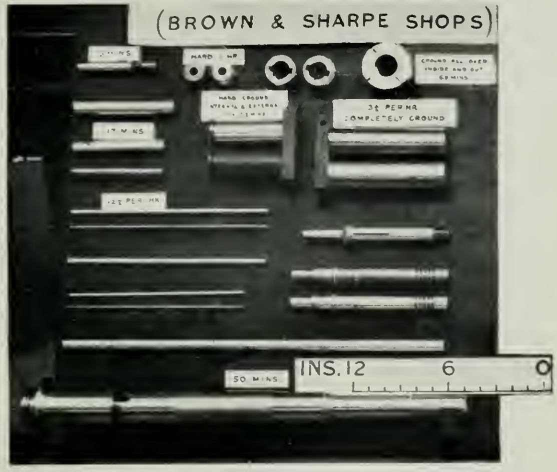


Fig. 30. *Steel Spindles, Cast-Iron and Gun-metal Parts.*

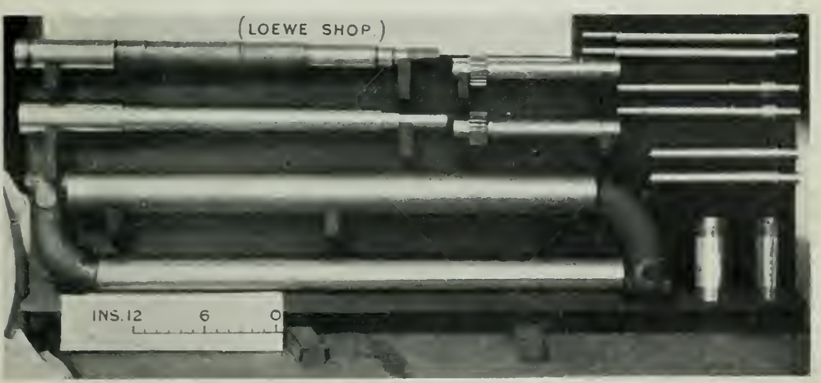
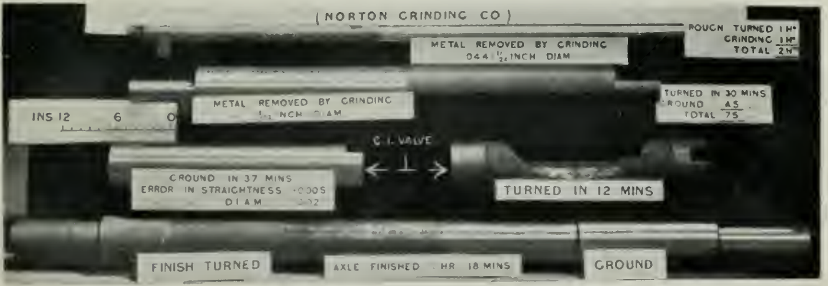


Fig. 31. *Shafts, Corliss Valve. and Axle.*



FENCING OF STEAM- AND GAS-ENGINES. *Plate 9.*

(*Mr. J. H. Crabtree's communication*)

Fig. 8. *Guards to Press-Cogs and to Gas-Engine.*

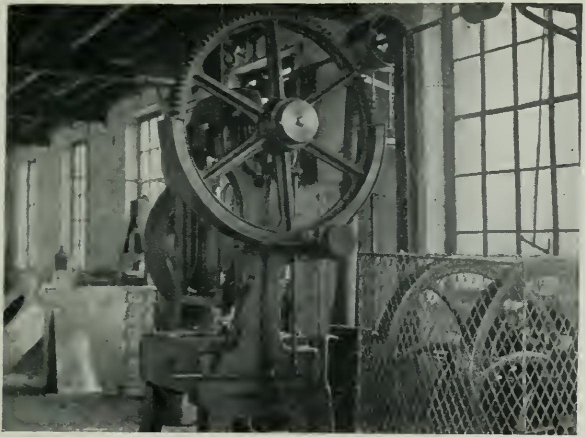


Fig. 9. *Fence to Gas-Engine.*

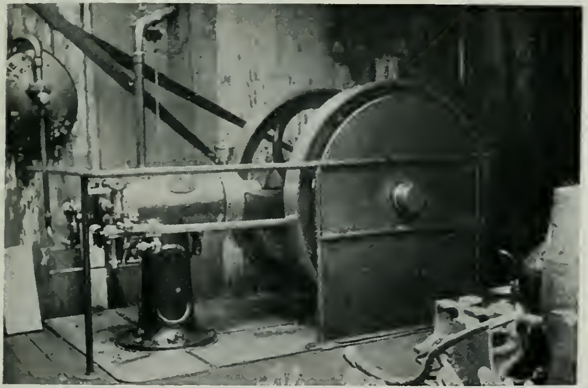
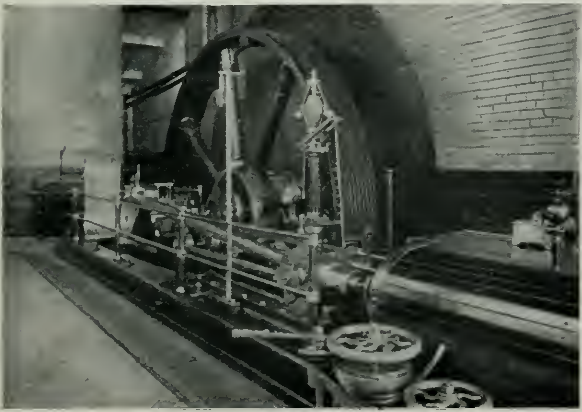


Fig. 10. *Fence to large Steam-Engine.*



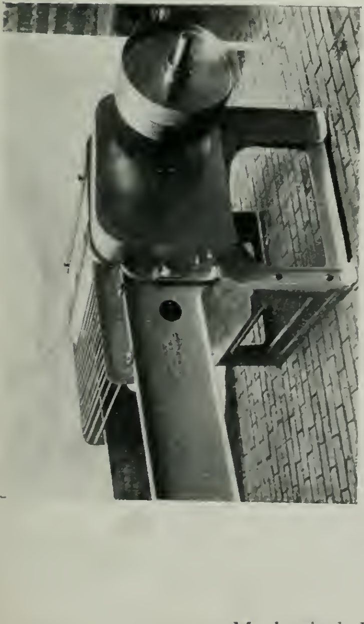


Fig. 1. *Guard over Taker-in Lattice, Bale-Breaker.*

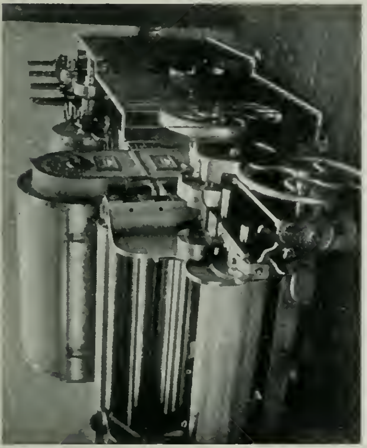


Fig. 2. *Board for turning end of Lap round Lap Roller, Single Scutcher and Lap Machine.*

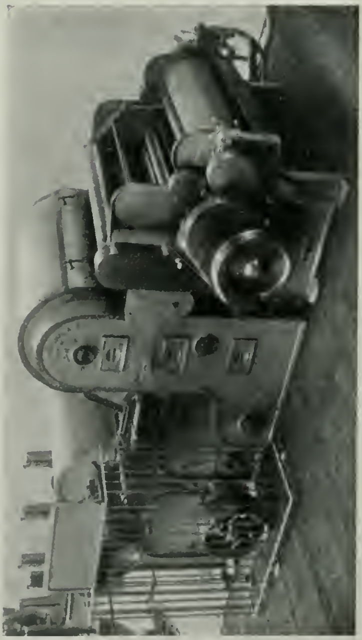


Fig. 3. *Single Scutcher and Lap Machine.*

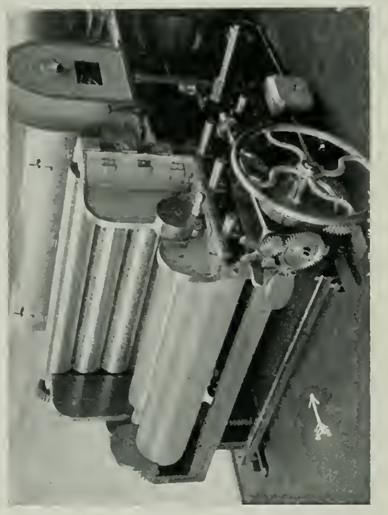


Fig. 4. *Opener or Scutcher, with Treadle full width of Machine.*

Exhaust Opener.

Fig. 5. *Beater Cover and Panel, End-door closed.*

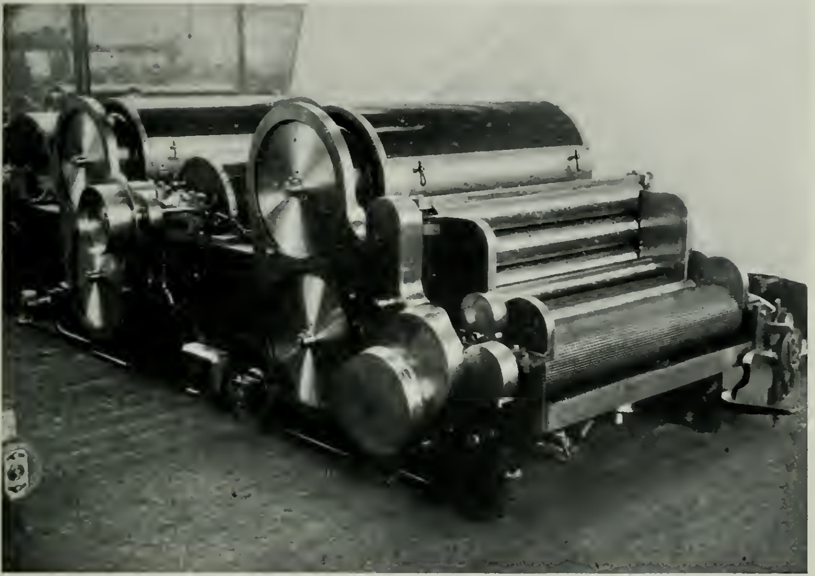
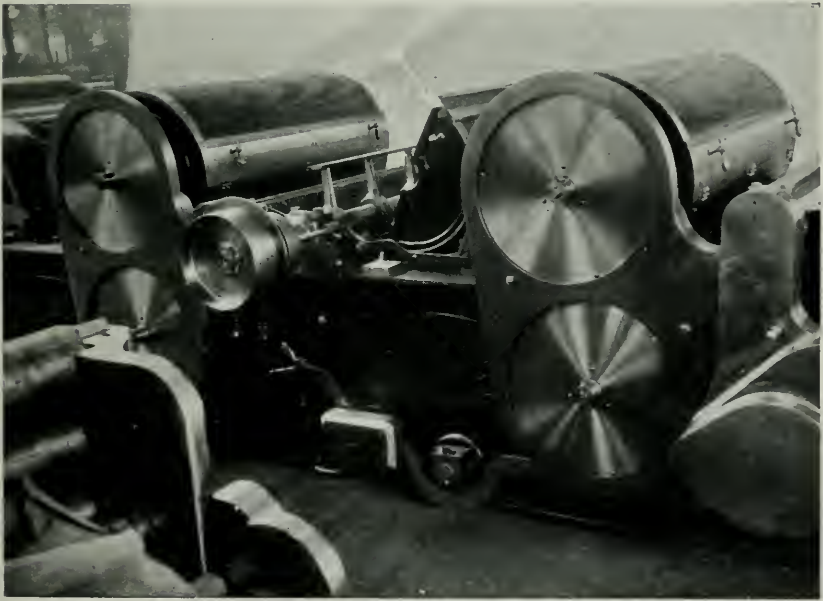


Fig. 6. *Beater Cover and Panel, End-door open.*



Carding Engine.

Fig. 7. *Complete Guard to Licker-in, Bevel-wheel, and Pinion.*

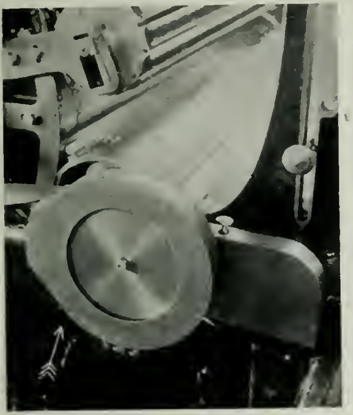


Fig. 8. *Partial Guard to Licker-in, Bevel-wheel, and Pinion.*

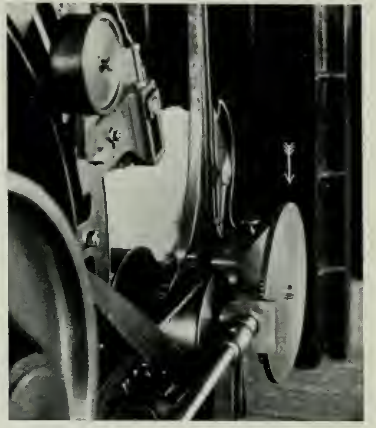


Fig. 9. *Complete Guard to Doffer and side shaft Bevels.*

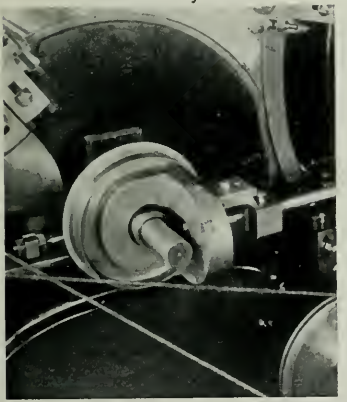


Fig. 10. *Complete Guard to large Spur-wheel.*

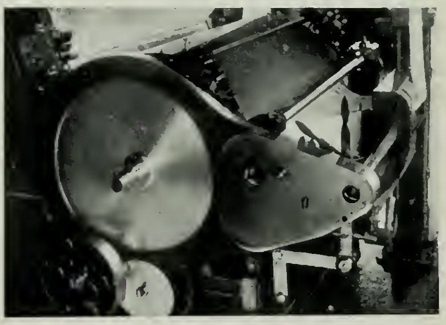
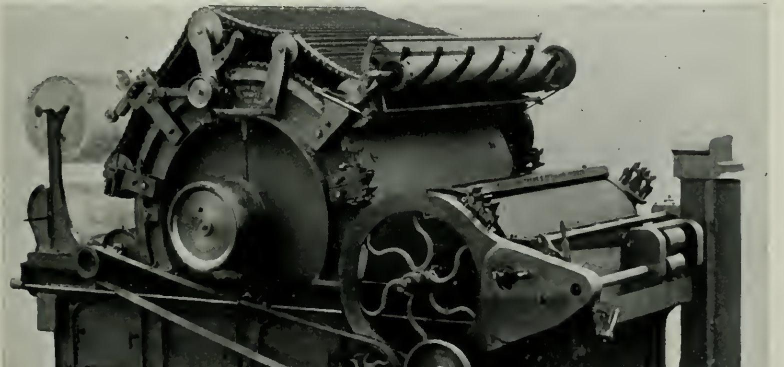


Fig. 11. *Strap Fork arrangement to stop the Machine from either front, middle, or back.*



GUARDING OF TEXTILE MACHINERY. *Plate 13.*

Drawing Frame.

Guard over Gearing.

Fig. 12. *Closed.*

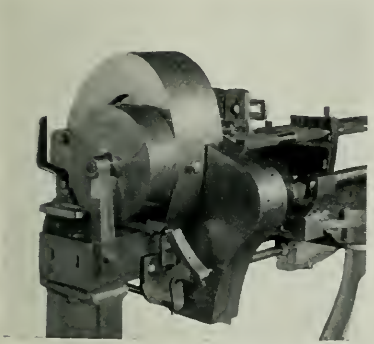
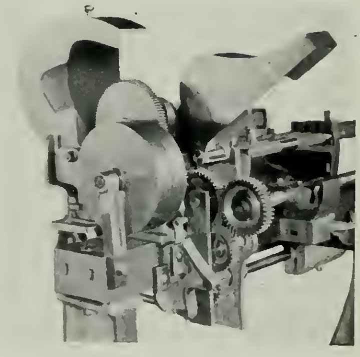


Fig. 13. *Open.*



Slubbing, Intermediate, and Roving Frames.

Automatic Locking Doors.

Fig. 14. ***Closed.***

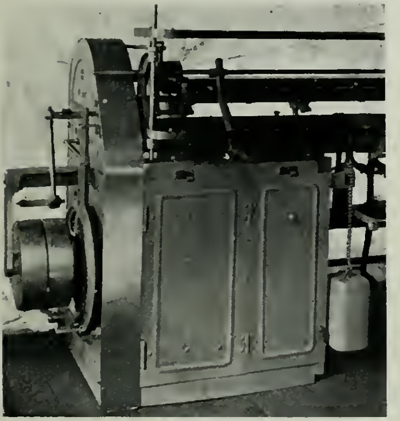
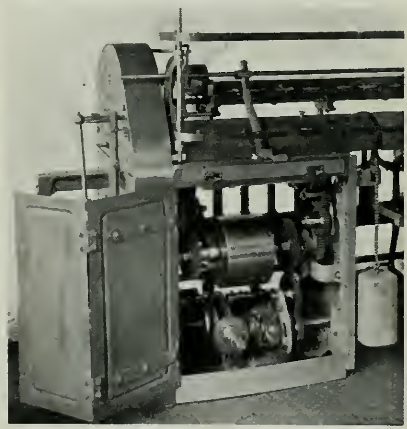


Fig. 15. *Open.*



Guard surrounding the Driving Pulleys.

Fig. 16. *Cast-iron Guard.*

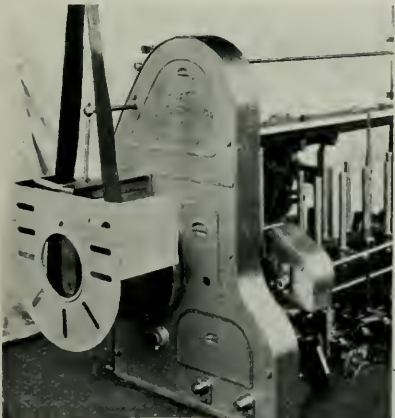
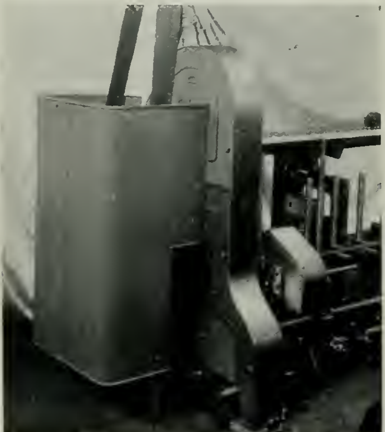


Fig. 17. *Sheet-iron Guard.*



Self-Acting Mule.

Fig. 18. *Headstock Guard over Rope Pulleys on Tail-pieces, &c.*

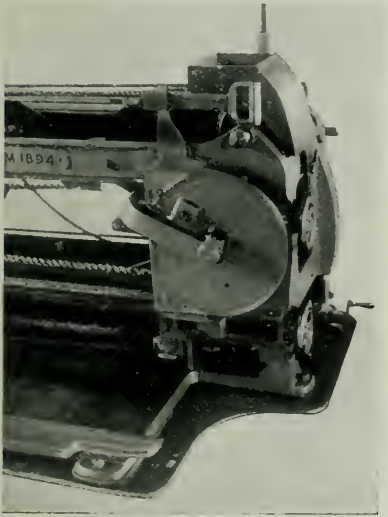


Fig. 19. *Rope Pulleys on Tail-piece, unguarded.*

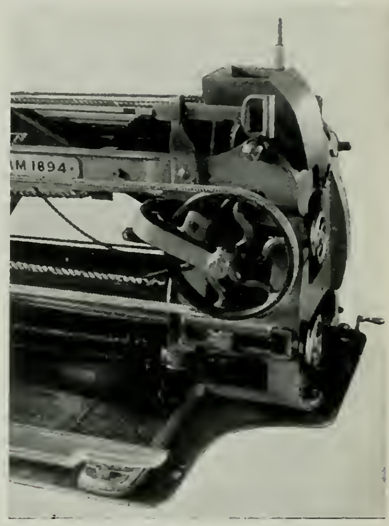


Fig. 20. *Headstock Back-Guard in Sheet-iron.*

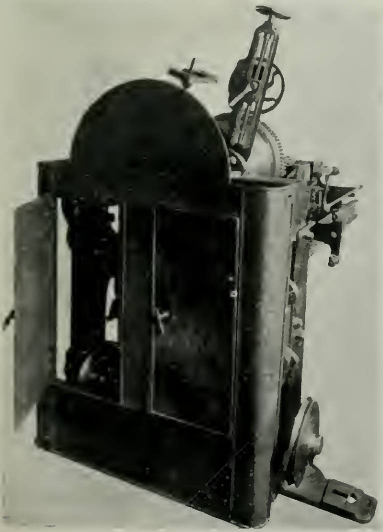
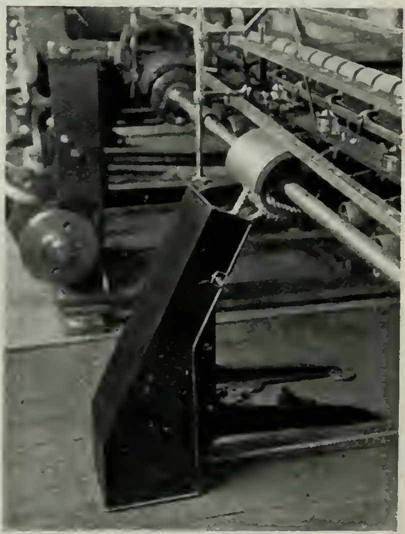


Fig. 21. *Guard to middle Drawing-out Scroll with Ropes.*



Self-Acting Mule (continued).

Fig. 22. *Guard to Floor Pulley of middle Drawing-out Band.*

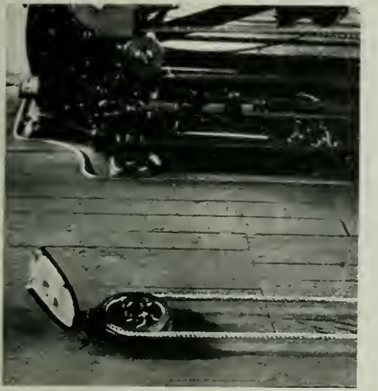


Fig. 23. *Guard over Drawing-out Scroll and Ropes on the out-end Framing.*

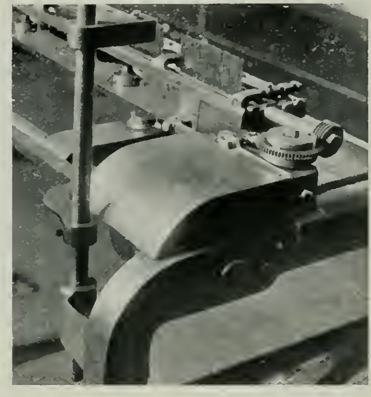


Fig. 24. *Guard to Carrier Pulley and Rope.*

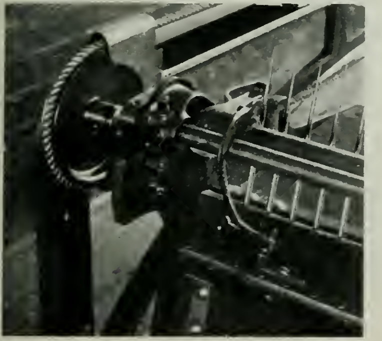


Fig. 25. *Guard to "Stop" on front Faller.*

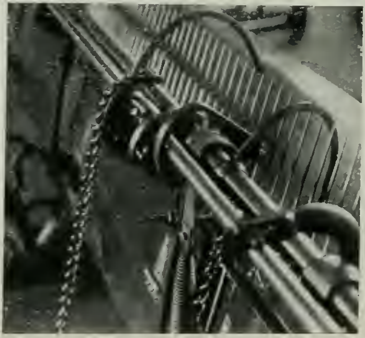
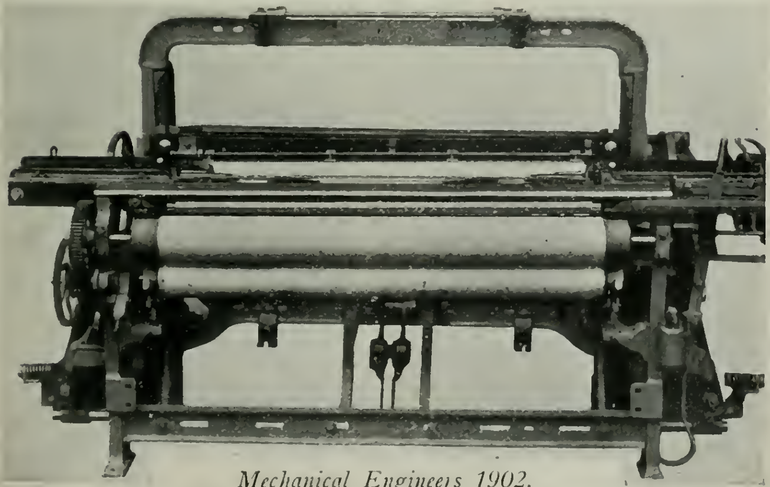


Fig. 27. *Calico Loom. Improved Shuttle-Guard.*



(Mr. J. H. Crabtree's communication.)

Cotton Mule, &c.

Fig. 28. *Guard to Drawband-Pulley.*

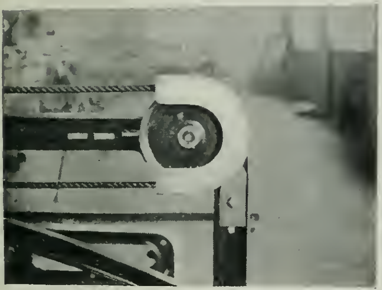


Fig 29. *Guard to Carriage Wheel.*

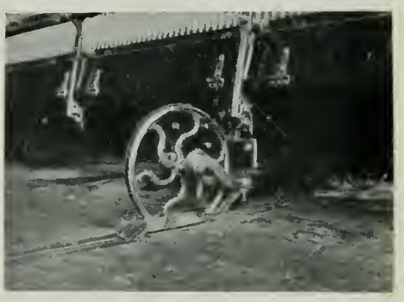


Fig. 30. *Guards on Headstocks.*

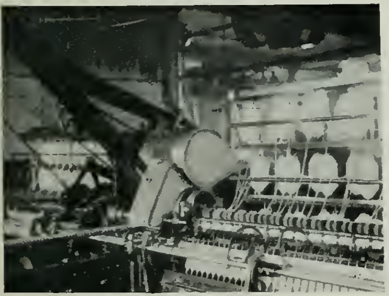


Fig. 31. *Plate Guard behind Headstocks.*

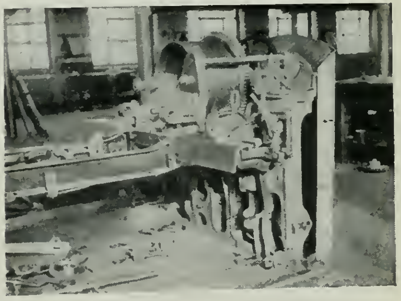


Fig 32. *Back of Headstocks.*

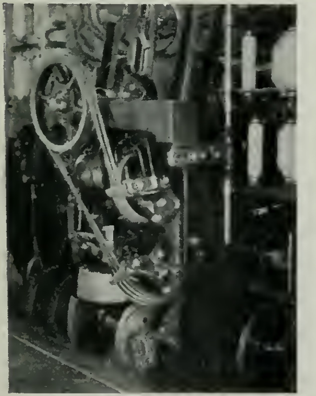
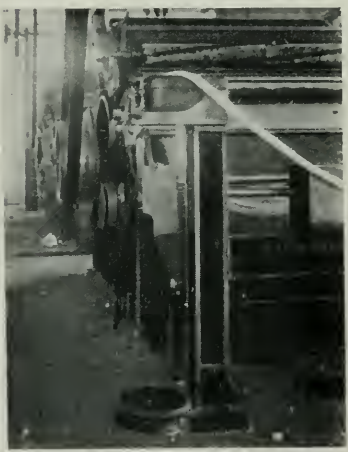


Fig. 33. *Guard for Carding Engine.*
(Fairclough.)



GUARDING OF TEXTILE MACHINERY. *Plate 17.*

(Mr. J. H Crabtree's communication—continued.)

Plate 17.

Shuttle Guards.

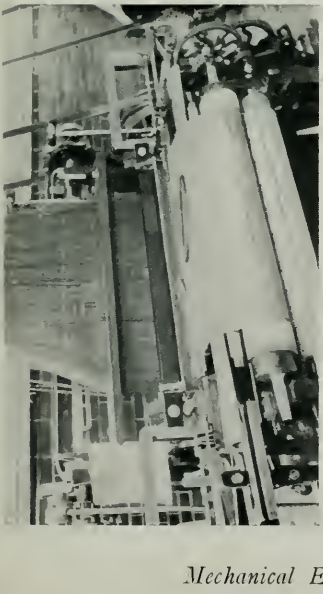


Fig. 34. *On Jacquard Loom.*

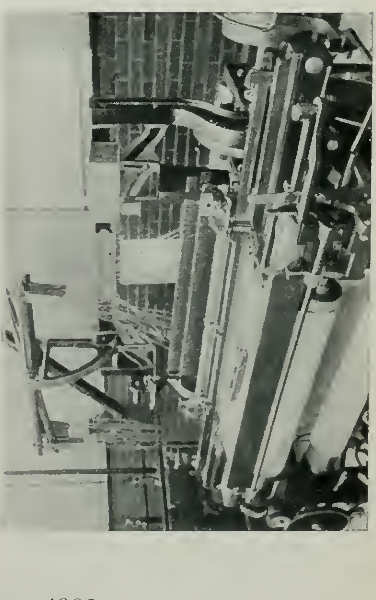


Fig. 35. *On ordinary Loom.*

Speed and Ring Frames.

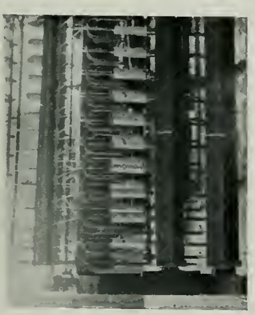


Fig. 36. *Guard to Bevels of Speed.*

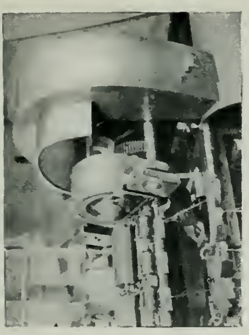


Fig. 37. *Guard to Ring Frame.*

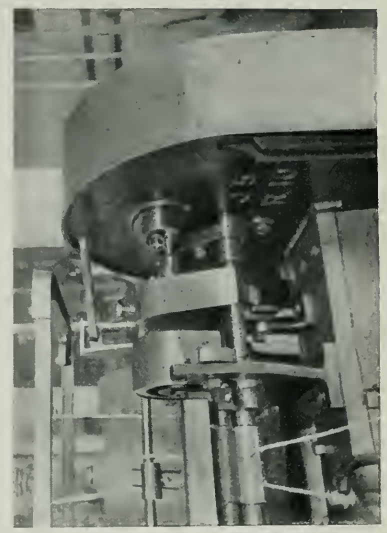


Fig. 38. *Guard for Draft Wheels of Speed.*

Plate 18.

Automatic Gate (Walker and Hildred).

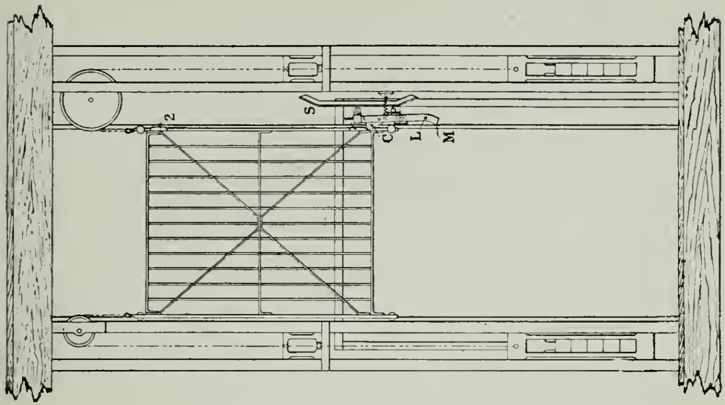


Fig. 3. Open.

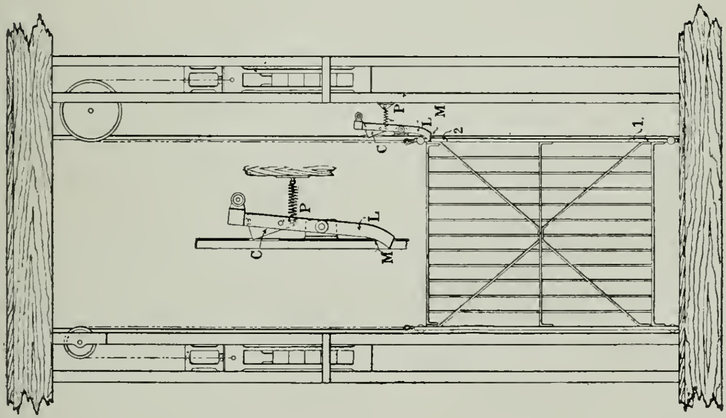


Fig. 2. Closed.

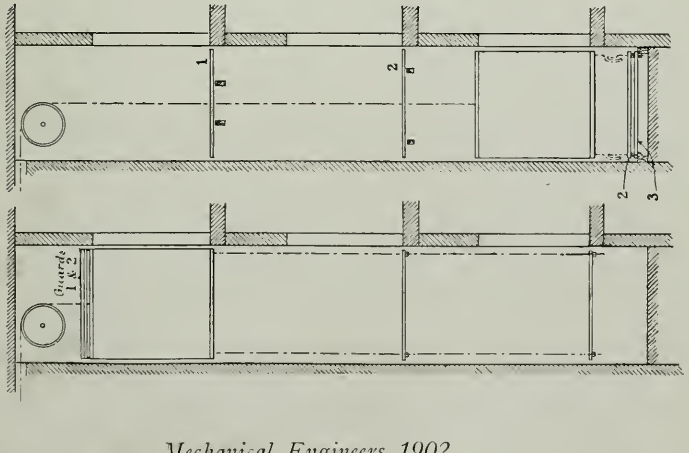


Fig. 1.
Lift Guards (McGee).

Automatic Gate (Sant).

Fig. 4. *Front Elevation.*

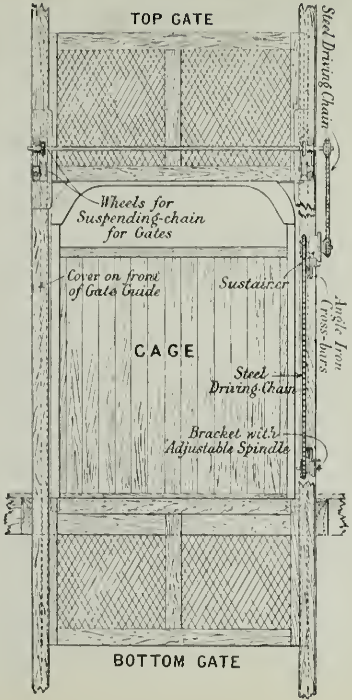

TOP GATE
Steel Driving Chain
Wheels for Suspending-chain for Gates
Cover on front of Gate Guide
Sustainer
Angle Iron Cross-bars
CAGE
Steel Driving Chain
Bracket with Adjustable Spindle
BOTTOM GATE

Fig. 5. *Side Elevations.*

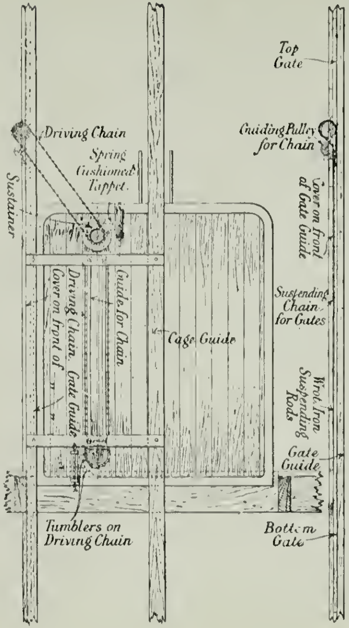
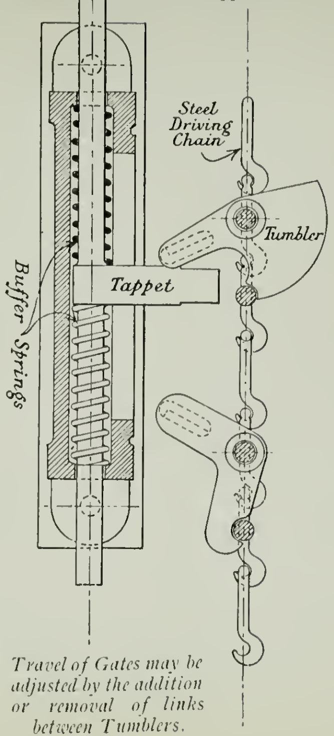


Fig. 6.
Detail of Spring-Cushioned Tappet.



Travel of Gates may be adjusted by the addition or removal of links between Tumblers.

Fig. 7. *Locking Gear.*
(Hollins-Amendt.)

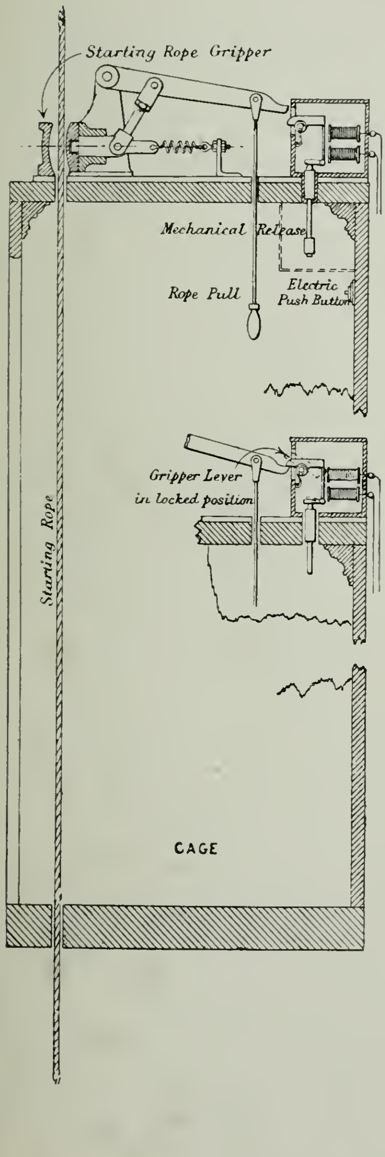


Fig. 8. *Hydraulic Semaphore Arm.*
(Stokes and Richmond.)

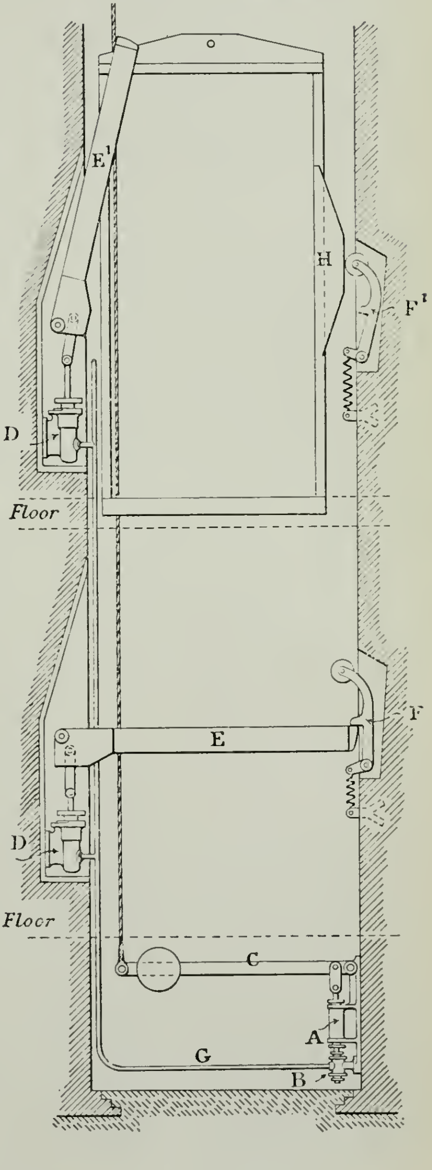
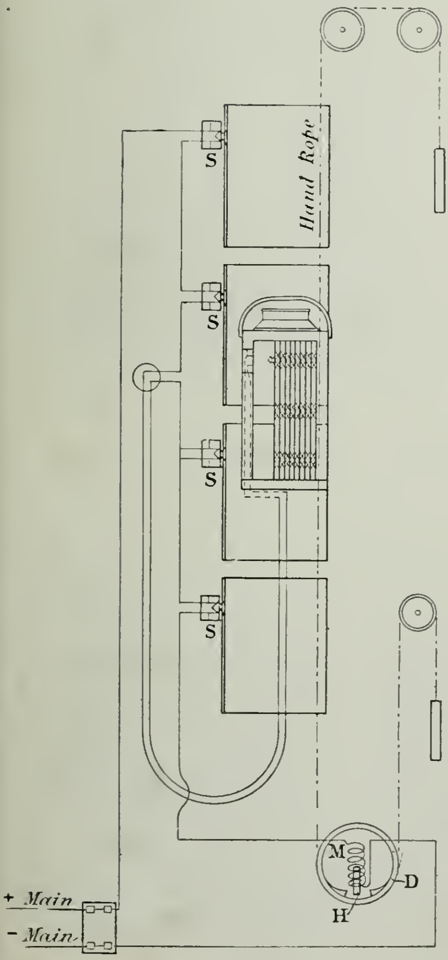


Fig 9.

Electric Locking-Gear for Controlling-Gear and Gates.

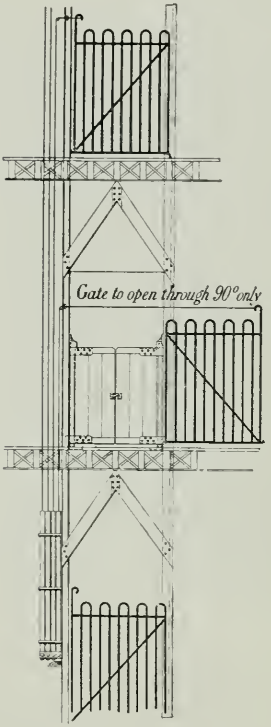
(Walker and Hildred.)



(Mr. H. H. Winston's remarks.)

Fig. 10.

Automatic Locking Gates released by outside operator.



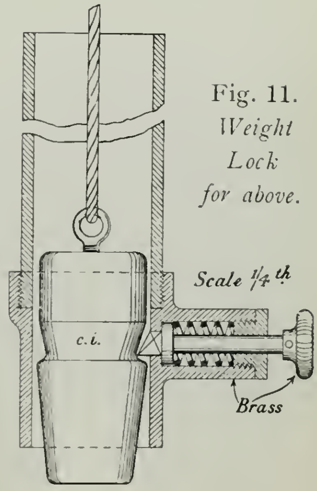


Fig. 11.

Weight Lock for above.

Planished Sheet-steel Bevel-wheel Guards.

Fig. 3. *To Drills.*

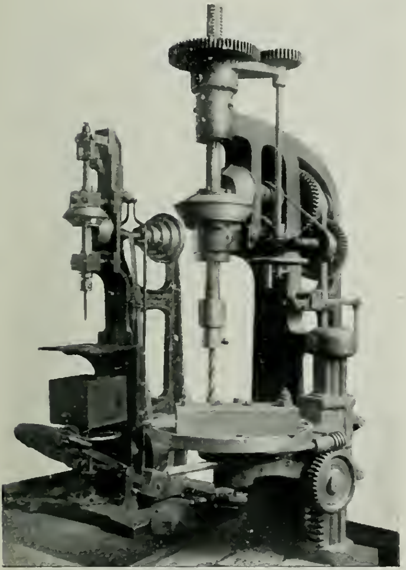


Fig. 4. *To Shafting.*

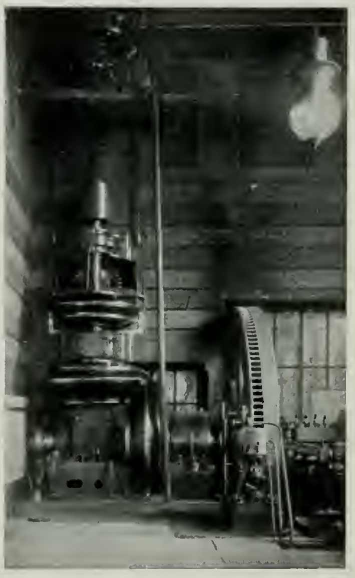


Fig. 5.
Bent Bar Guard over Emery Wheel.

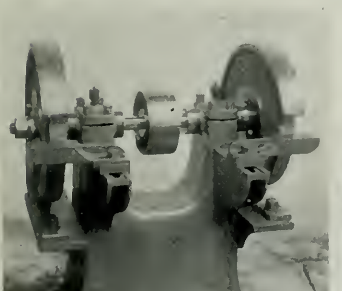


Fig. 6.
Planished Sheet-steel Wheel Guards on Sliding Surfacing Lathe.

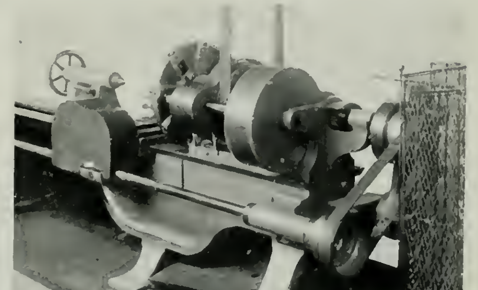
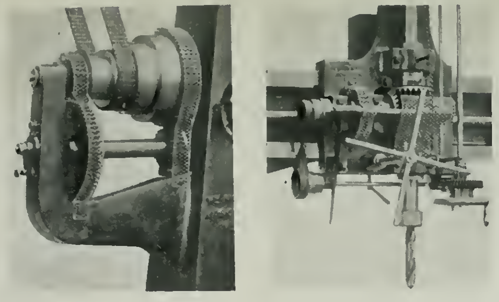


Fig. 7. *Wire Guards, Radial Arm Drill.*

Back-Gear. *Carriage-Gear.*



Guard over Horizontal Shaft and Coupling.

Fig. 8. *In position.*

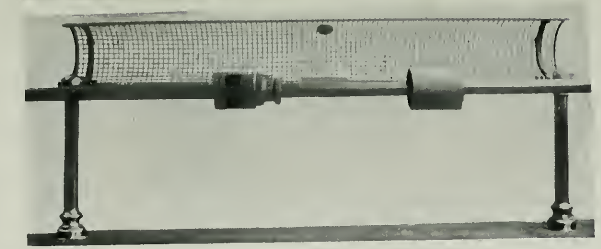


Fig. 9. *Open for oiling.*

Protection of Driving Belt.

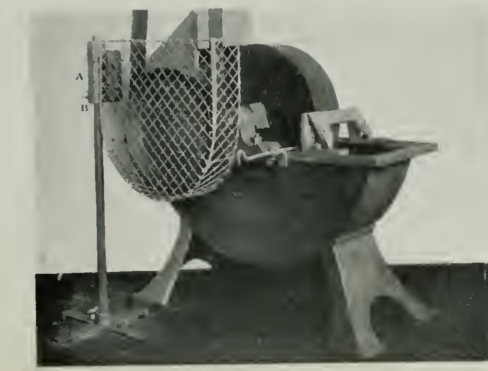


Fig. 10. *Fixed Guard. Closed.*

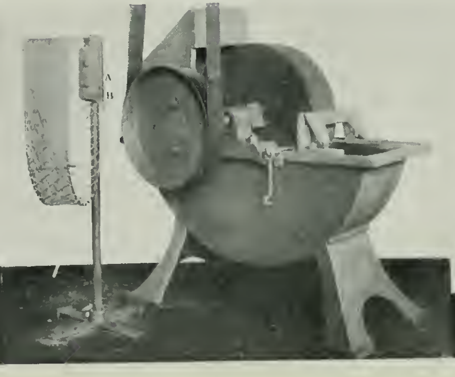


Fig. 11. *Fixed Guard. Open.*

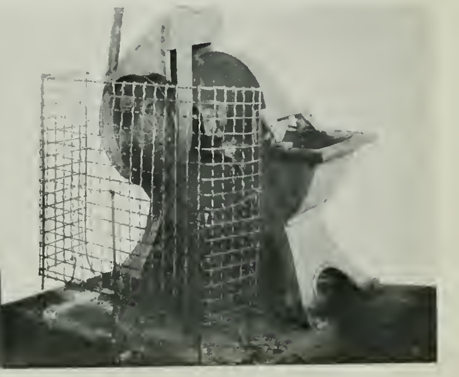
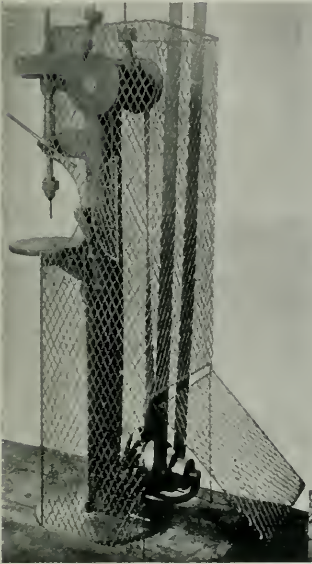


Fig. 12. *Movable Guard.*

GUARDING MACHINE TOOLS.

Plate 24.

Fig 13. *Dangerous Guard.*



Perfect Guard.

Fig. 14. *Closed.*

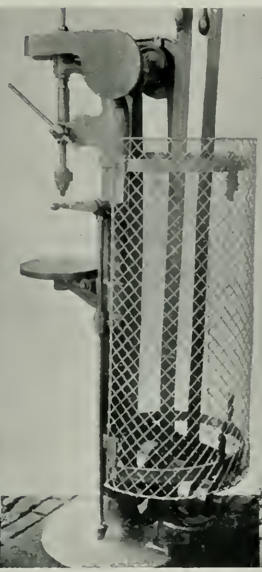
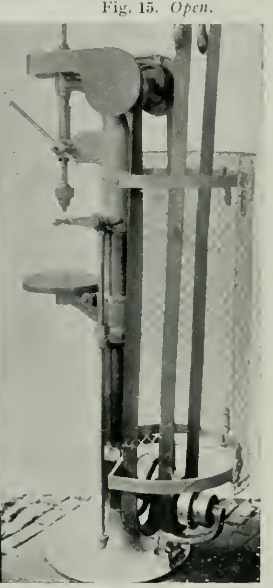


Fig. 15. *Open.*



Fencing of Change Wheels, &c., large Lathes.

Fig. 16. *Closed.*

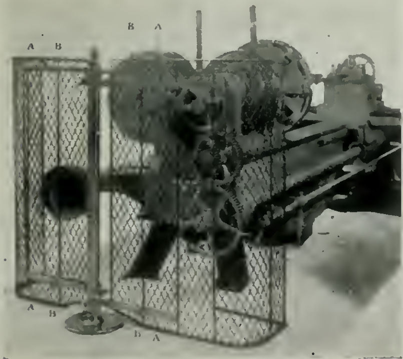
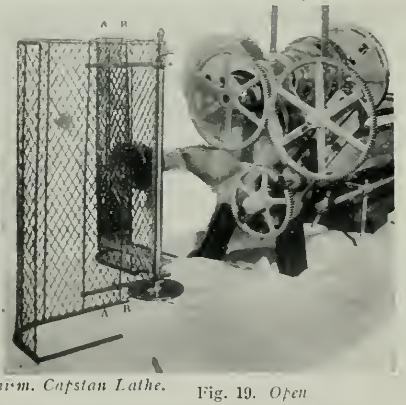


Fig 17. *Open.*



Guard to Feed Mechanism. Capstan Lathe.

Fig. 18. *Closed.*

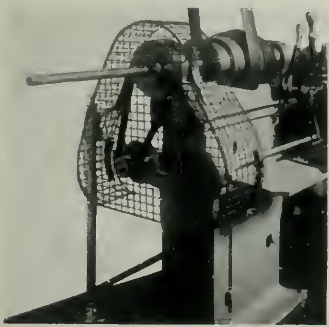
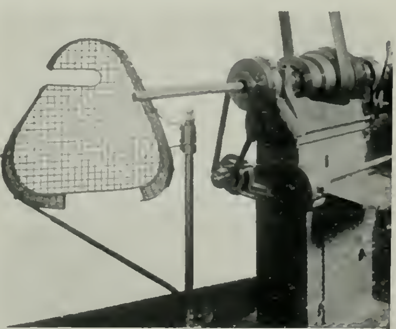


Fig. 19. *Open*



Mechanical Engineers 1902.

(*Mr. Oscar Harmer's remarks.*)

Fig. 21. *Complete Guards to Back- and Feed-Gears and Table movements of large Vertical Milling-Machine.*

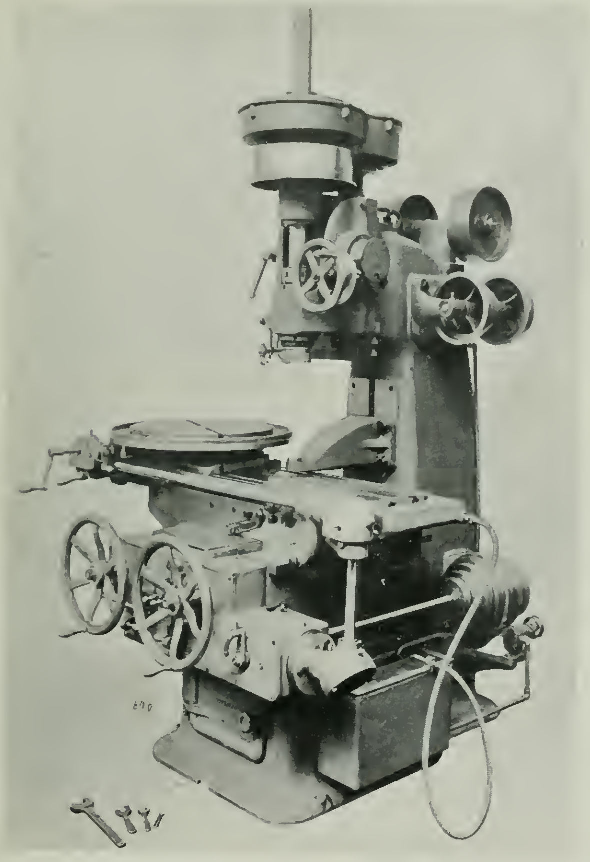
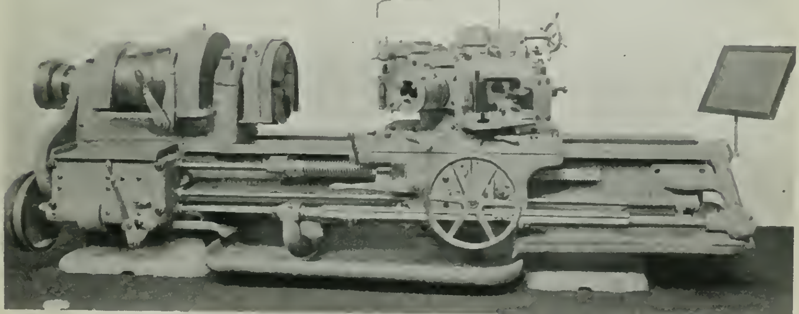


Fig. 22. *Guards to Headstock, Chuck, Feed, Apron, and other Gears of large Turret Lathe.*



GUARDING MACHINE TOOLS. *Plate 26.*

(*Mr. J. H. Crabtree's communication.*)

Fig. 23. *Guards to Emery Wheels.*

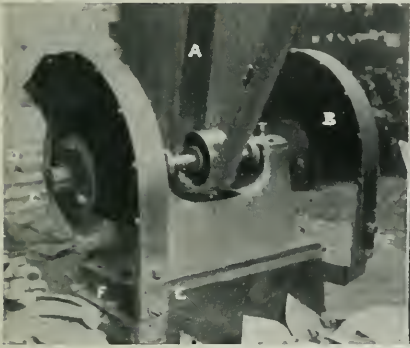


Fig. 26. *Guard to Guillotine.*

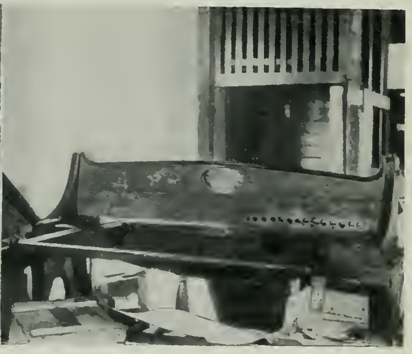


Fig. 24. *Guard to Circular Saw.*

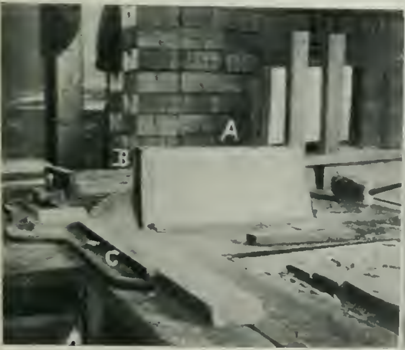


Fig. 27. *Guard to Tin-Plate Bending Machine.*

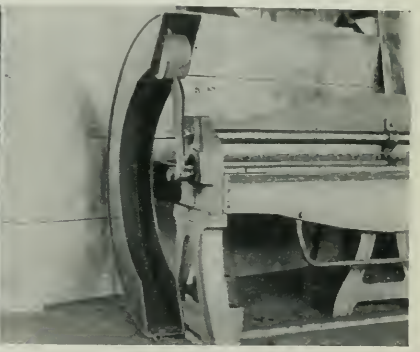


Fig. 25. *Guard to Circular Saw.*

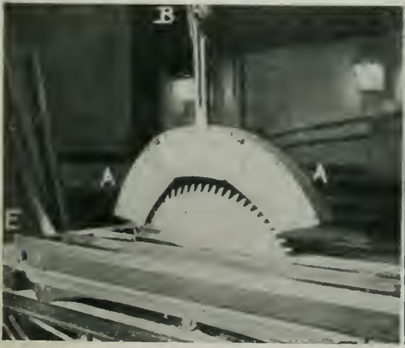
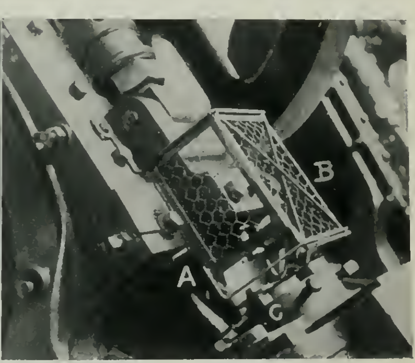
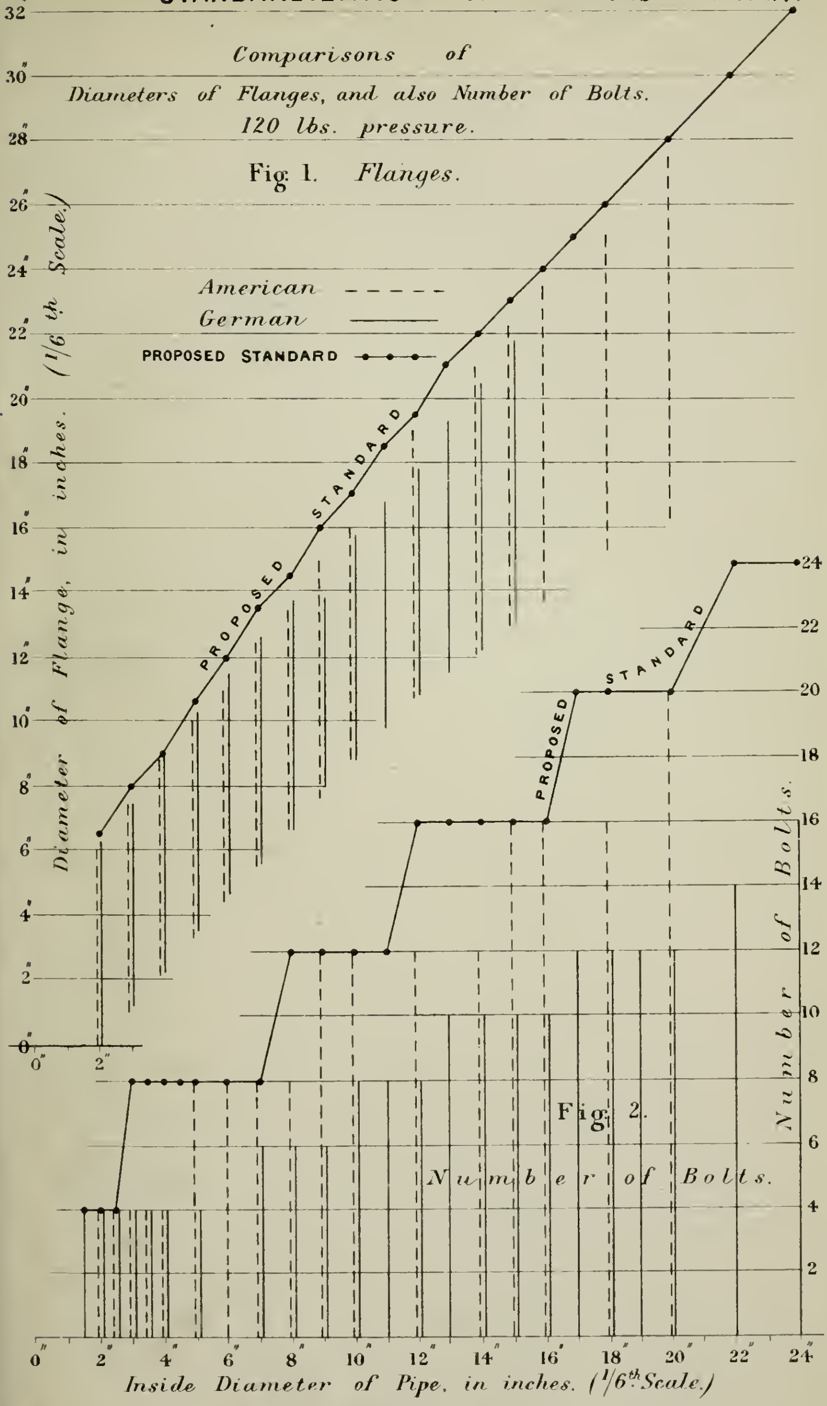


Fig. 28. *Guard to Power Press.*

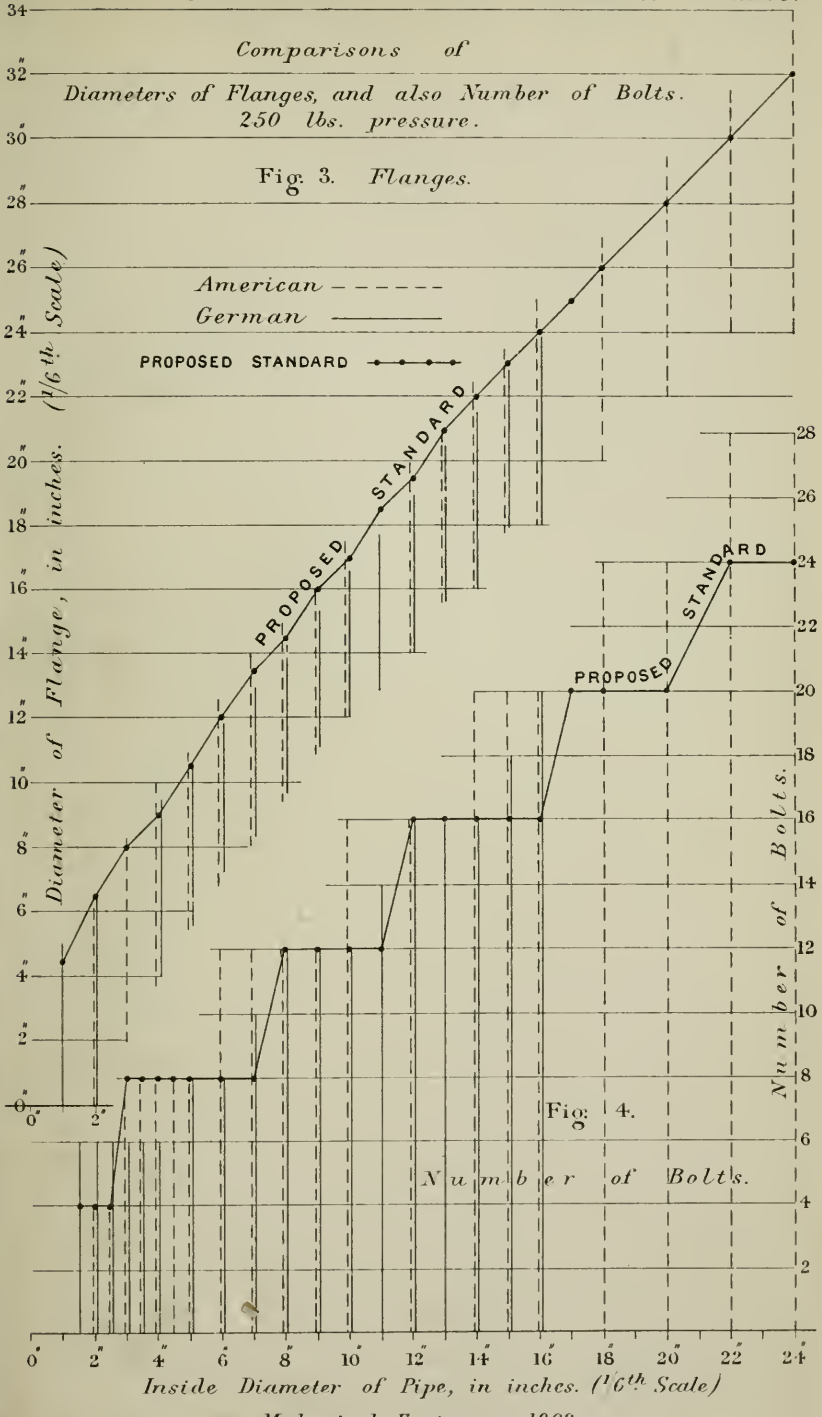


STANDARDIZATION OF FLANGES. *Plate 27.*



Mechanical Engineers 1902.

STANDARDIZATION OF FLANGES. *Plate 28.*



Comparisons of

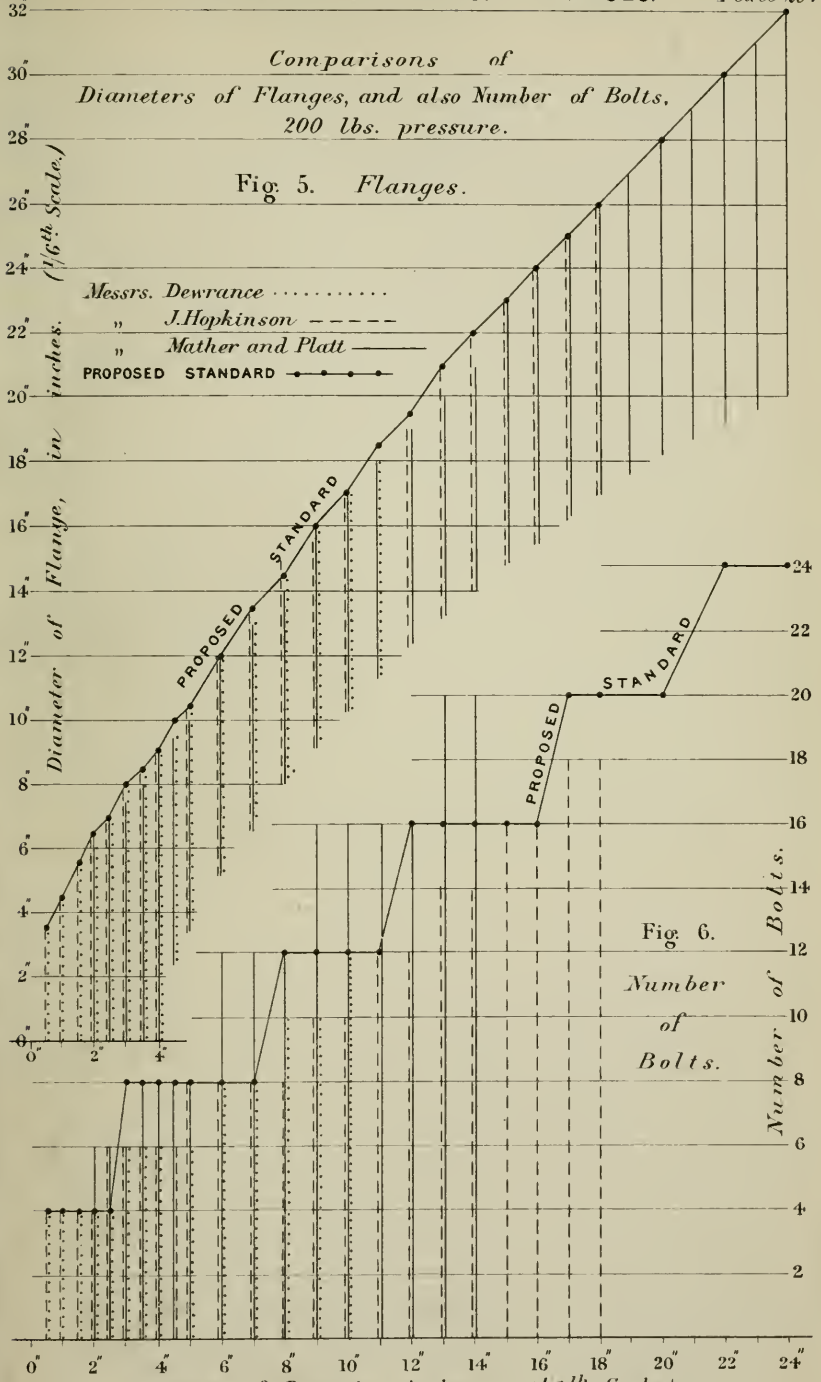
Diameters of Flanges, and also Number of Bolts.
250 lbs. pressure.

Fig. 3. *Flanges.*

Fig. 4. *Number of Bolts.*

Mechanical Engineers 1902.

STANDARDIZATION OF FLANGES. *Plate 29.*



Comparisons of Diameters of Flanges, and also Number of Bolts, 200 lbs. pressure.

Fig. 5. *Flanges.*

Fig. 6. *Number of Bolts.*

Mechanical Engineers 1902.

STANDARDIZATION OF FLANGES. *Plate 30.*

Comparisons of Dimension A (Table XIII) *on Flanged Fittings and Connections.*

Fig. 7.

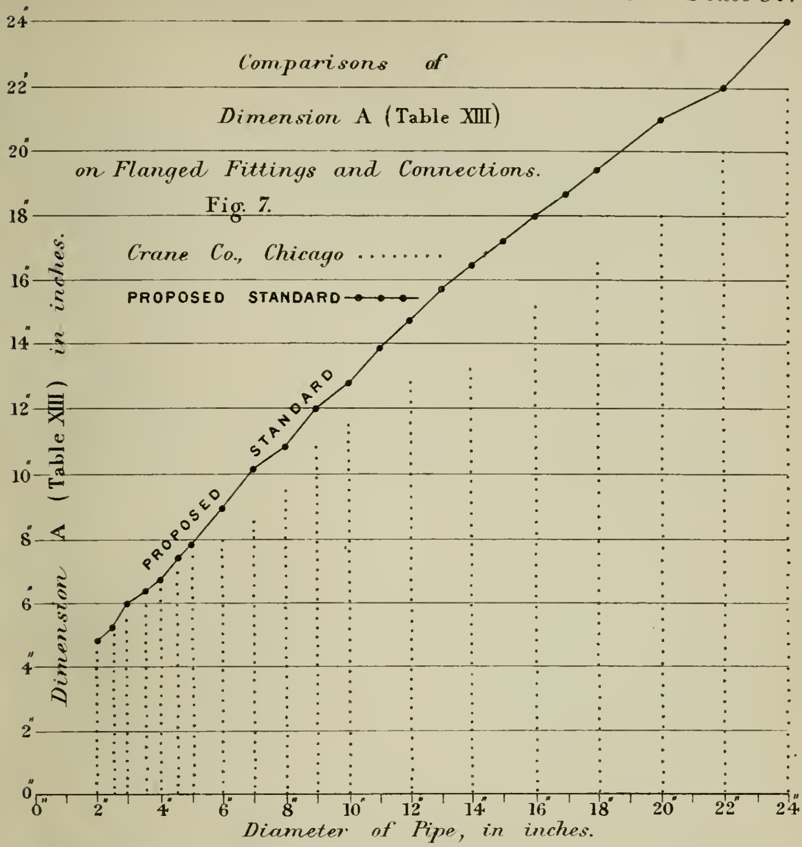
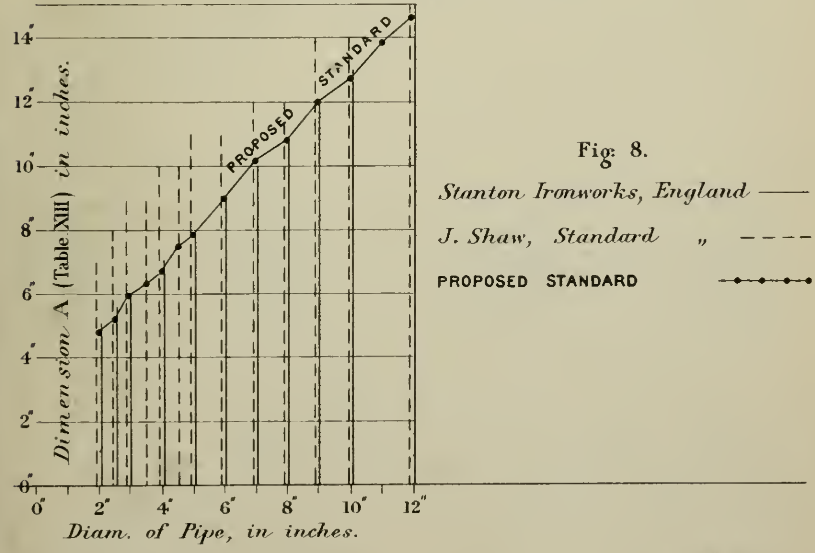


Fig. 8.



Mechanical Engineers 1902. *Scale 1/6th.*

STANDARDIZATION OF FLANGES. *Plate 31.*

Flanged Joints.

Fig. 9.

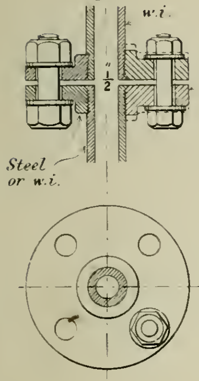


Fig. 10.

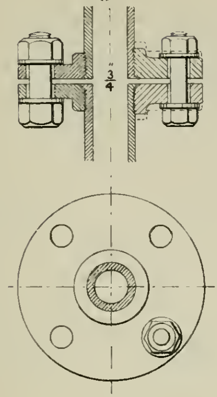


Fig. 11.

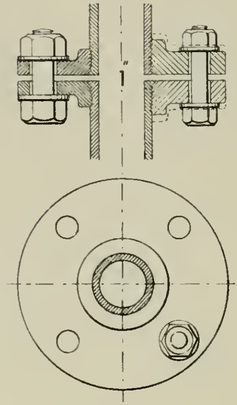


Fig. 12.

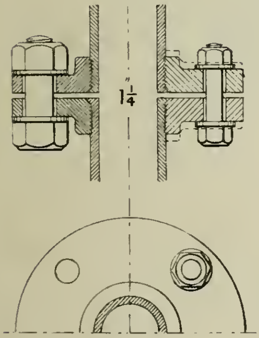


Fig. 13.

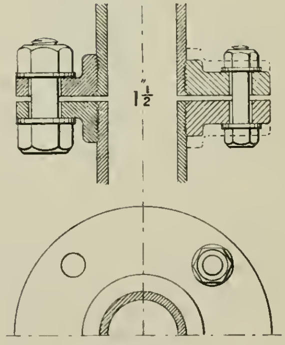


Fig. 14.

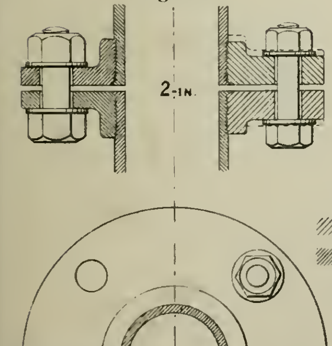
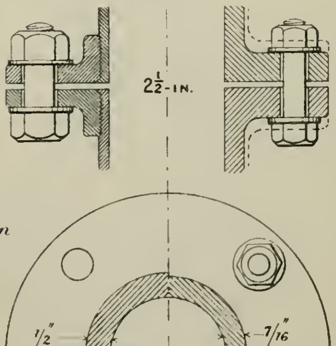


Fig. 15.



▨ = *Cast-iron*

▨ = *Steel*

or w.i.

Mechanical Engineers 1902.

Scale ¼th.

0 1 2 3 4 5 *Inches*

STANDARDIZATION OF FLANGES.

Flanged Joints.

Fig: 16.

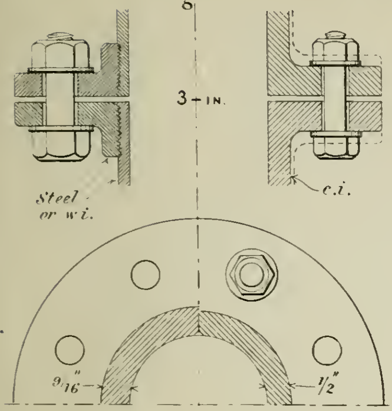


Fig: 17.

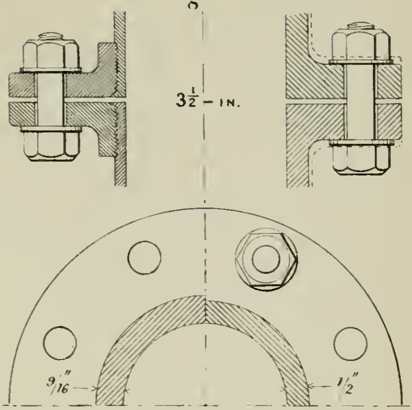


Fig: 18.

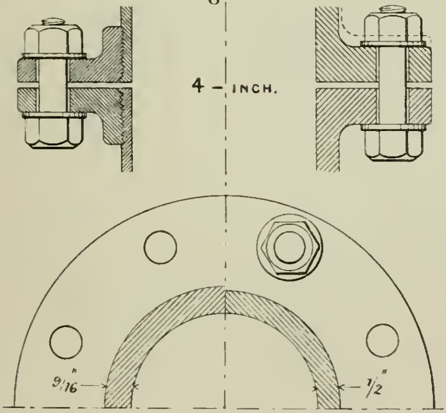
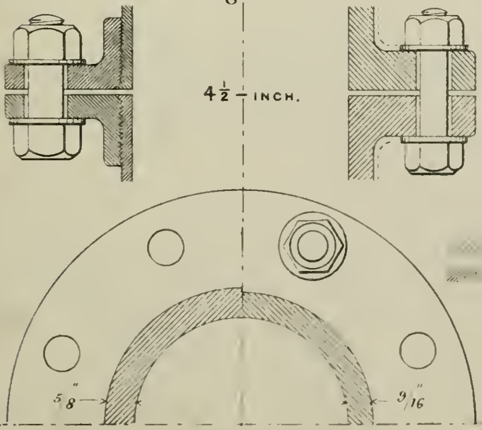


Fig: 19.



▨ = *c.i.*
▨ = *Steel or w.i.*

Mechanical Engineers 1902.

Scale ¼th

STANDARDIZATION OF FLANGES. *Plate 33.*

Flanged Joints.

Fig. 20.

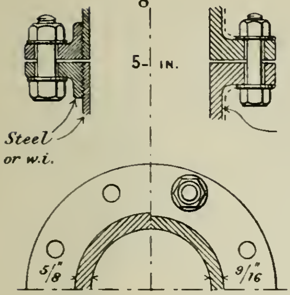


Fig. 21.

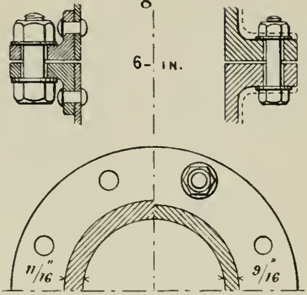


Fig. 22.

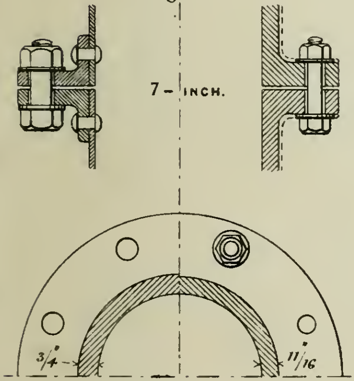


Fig. 23.

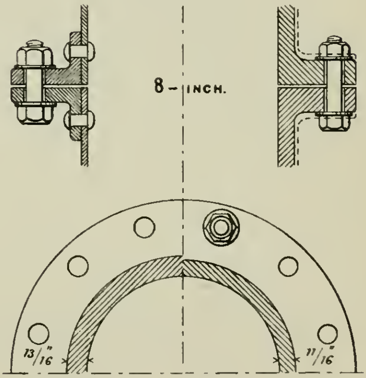


Fig. 24.

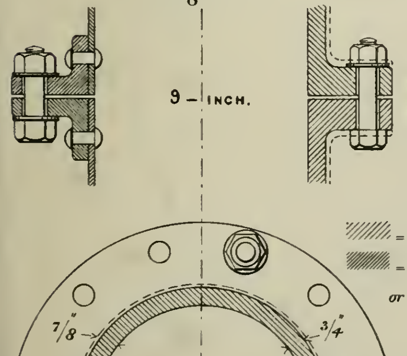
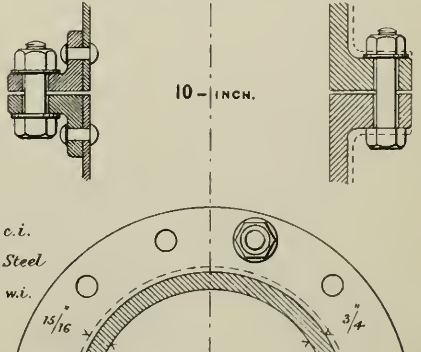


Fig. 25.



▨ = c.i.
▨ = Steel or w.i.

Mechanical Engineers 1902.

Scale 1/8th.

Flanged Joints.

Fig. 26.

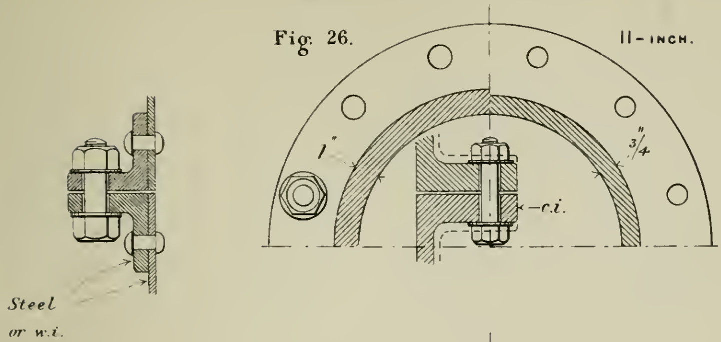


Fig. 27.

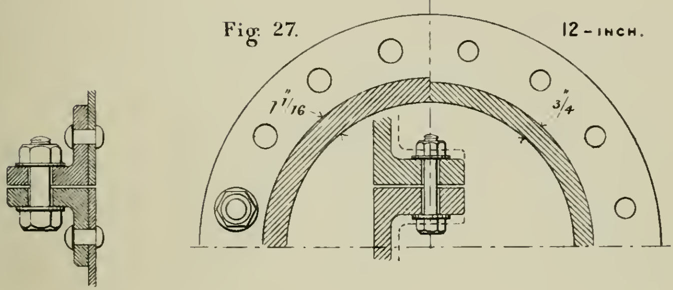
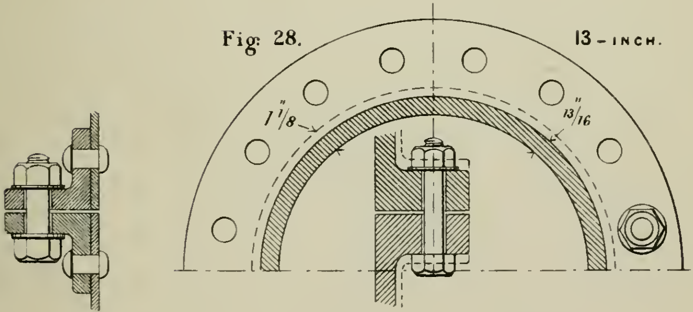
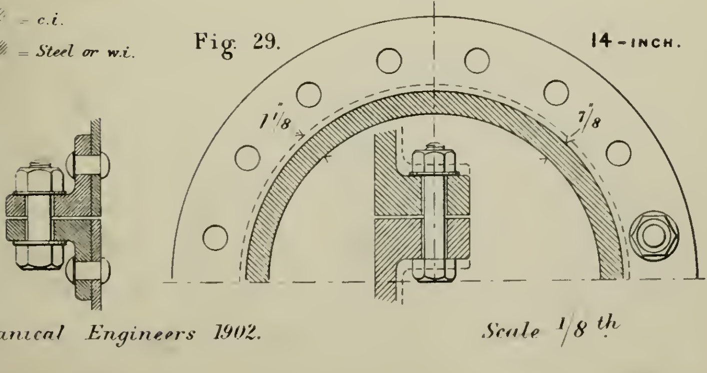


Fig. 28.



▨ = c.i.
▨ = Steel or w.i.

Fig. 29.



Mechanical Engineers 1902. *Scale 1/8 th.*

STANDARDIZATION OF FLANGES. *Plate 35.*

Flanged Joints.

Fig: 30.

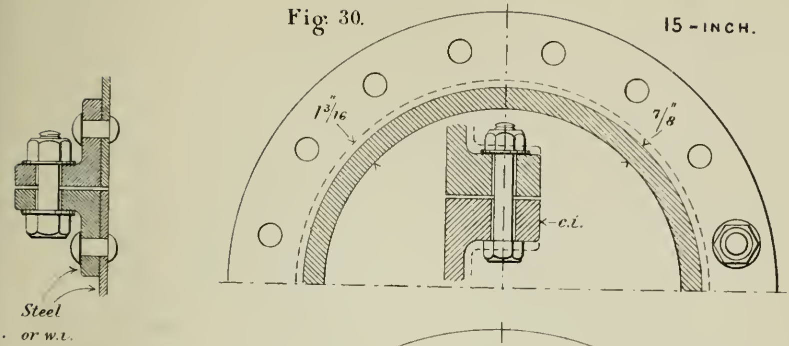


Fig: 31.

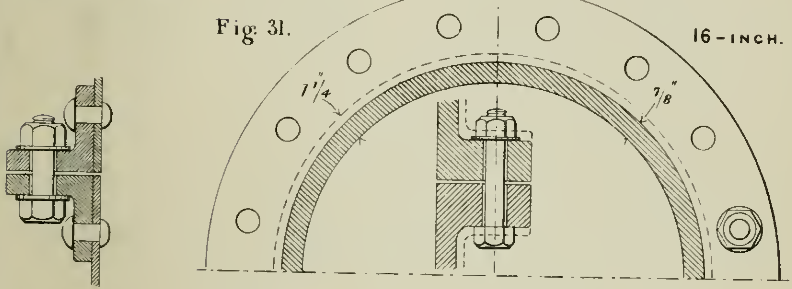


Fig: 32.

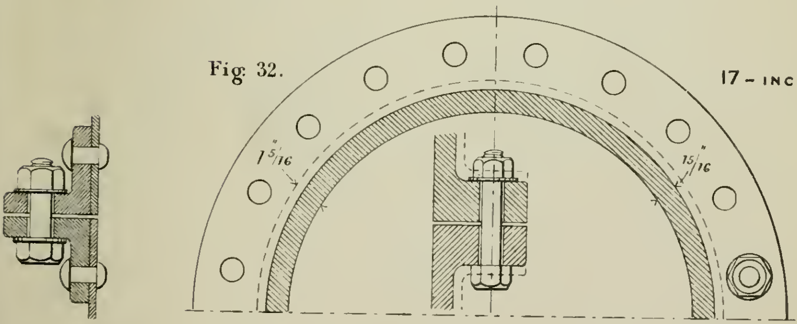
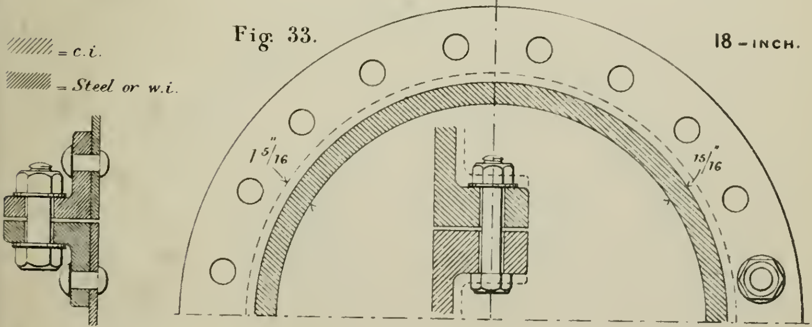


Fig: 33.



Mechanical Engineers 1902.

Scale 1/8th

STANDARDIZATION OF FLANGES. *Plate 36.*

Flanged Joints.

Fig. 34.

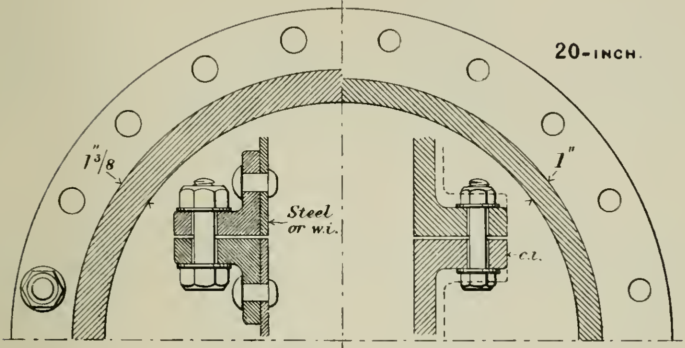


Fig. 35.

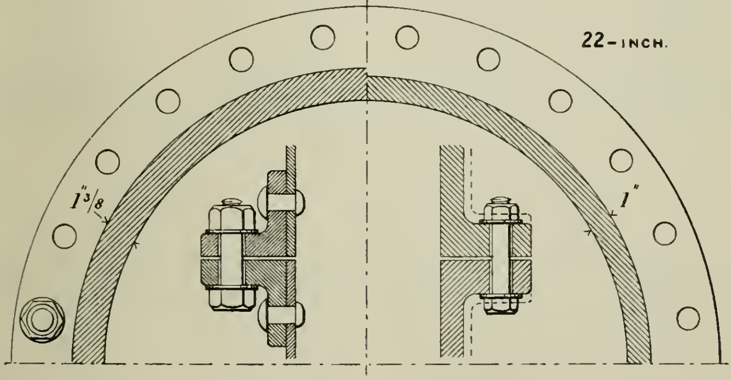
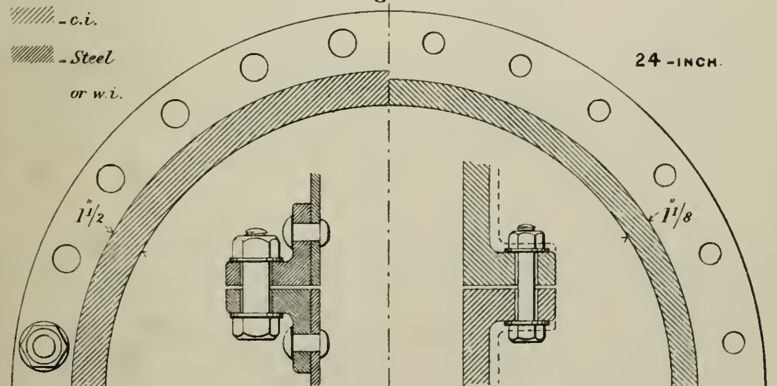


Fig. 36.



Mechanical Engineers 1902. *Scale 1/8th.*

STANDARDIZATION OF FLANGES. *Plate 37.*

Various Forms of Flanged Joints.

Fig. 37.

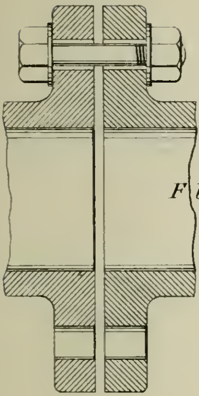


Fig. 38.

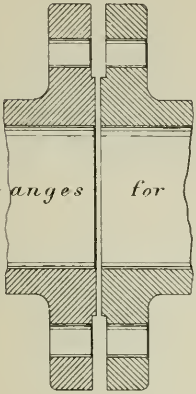


Fig. 39.

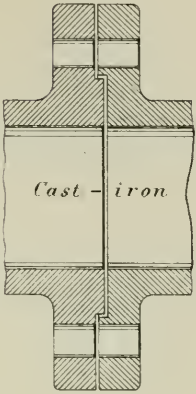
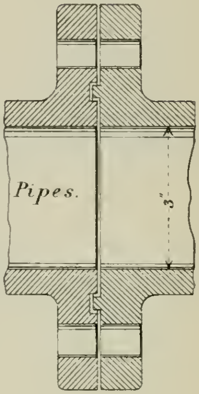


Fig. 40.



Flanges for Cast-iron Pipes.

Fig. 41.

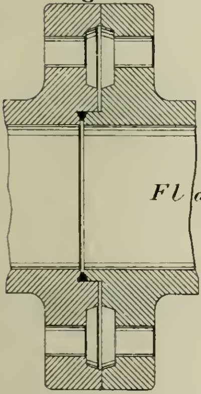


Fig. 42.

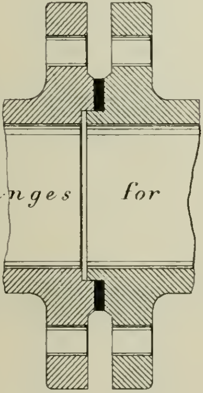


Fig. 43.

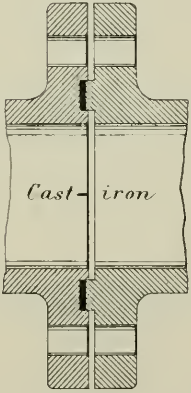
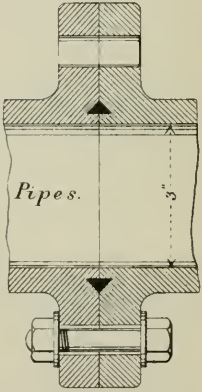


Fig. 44.



Flanges for Cast-iron Pipes.

Fig. 45.

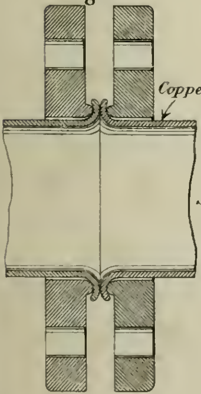


Fig. 46.

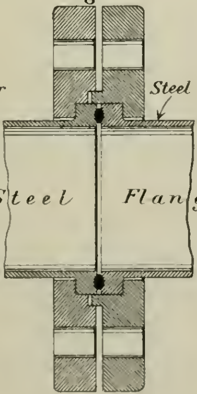


Fig. 47.

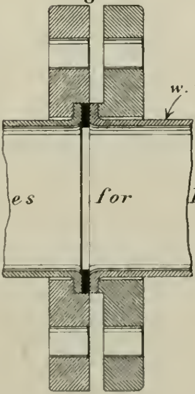
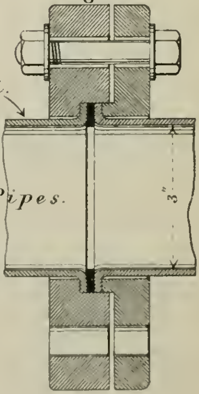


Fig. 48.

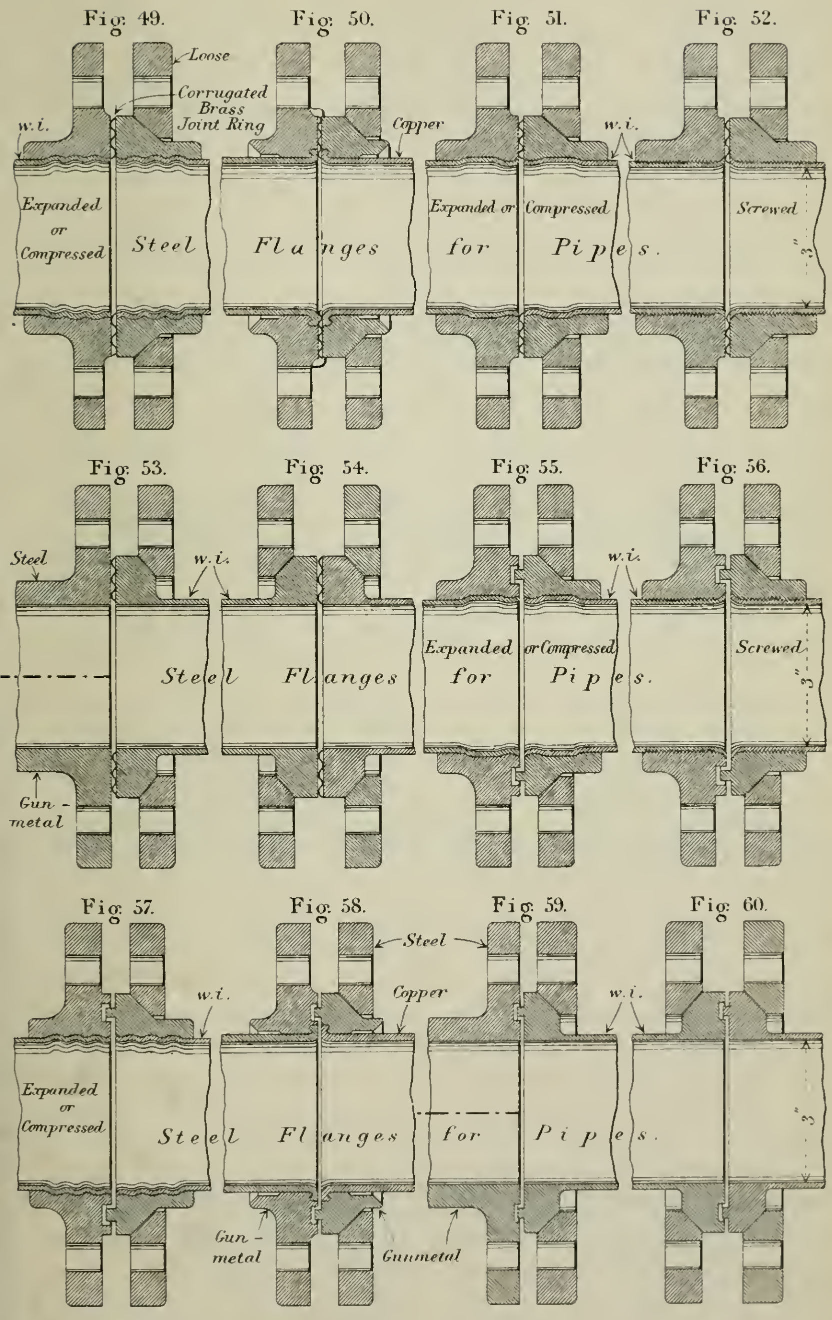


Steel Flanges for Pipes.

Scale 1/4th

STANDARDIZATION OF FLANGES. *Plate 38.*

Various Forms of Flanged Joints.



Mechanical Engineers 1902. *Scale 1/4th.*

STANDARDIZATION OF FLANGES. *Plate 39.*

Various Forms of Flanged Joints.

Fig. 61.

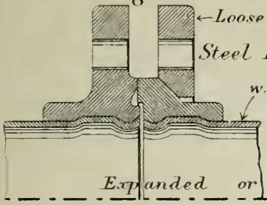


Fig. 62.

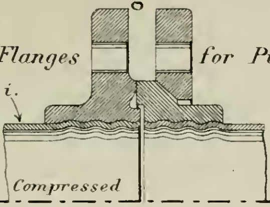


Fig. 63.

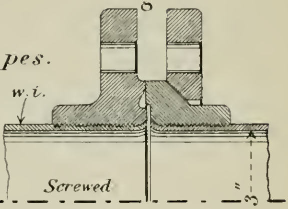


Fig. 64.

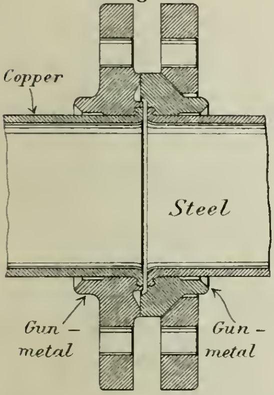


Fig. 65.

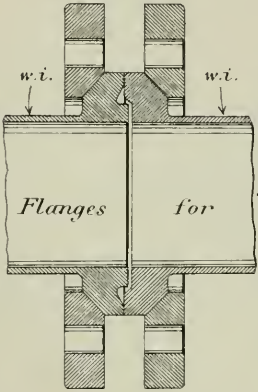


Fig. 66.

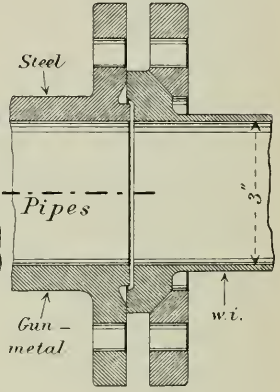


Fig. 67.

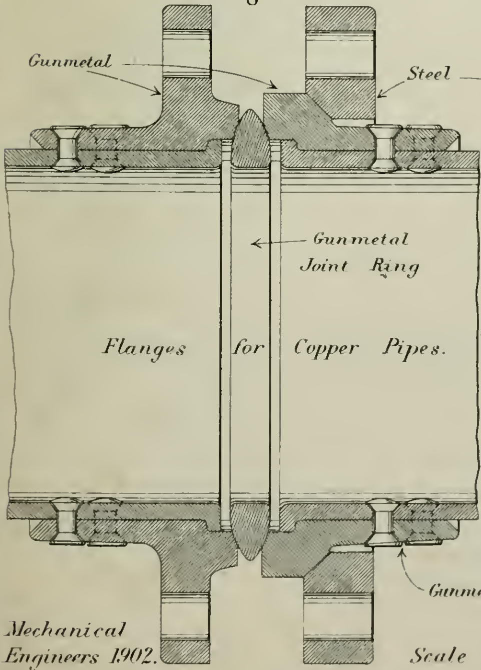
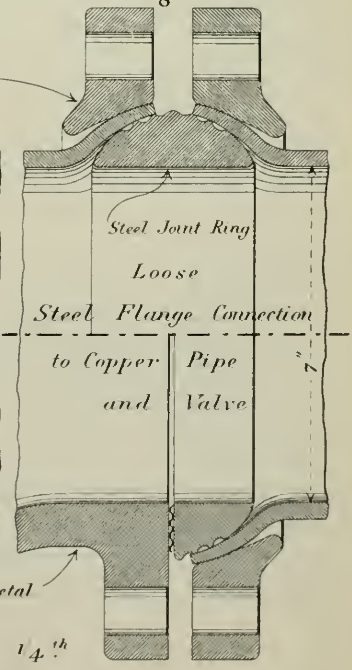


Fig. 68.



Mechanical Engineers 1902.

Scale ¼th

STANDARDIZATION OF FLANGES.

(*Mr. George Addy's remarks.*)

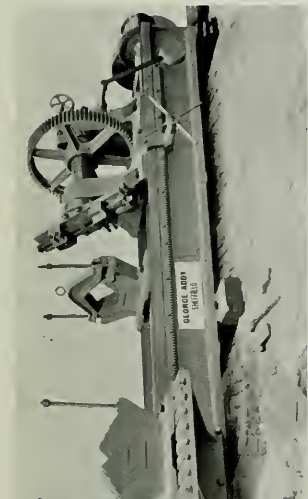


Fig. 96.
Double Horizontal Facing Lathe for Pipe Flanges.

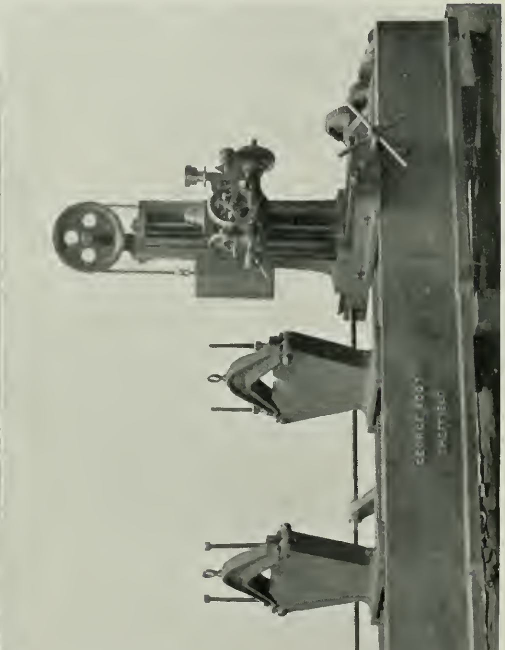


Fig. 97. *Double Horizontal Drilling Machine for Pipe Flanges.*

Fig. 1. *Turning Gear.*

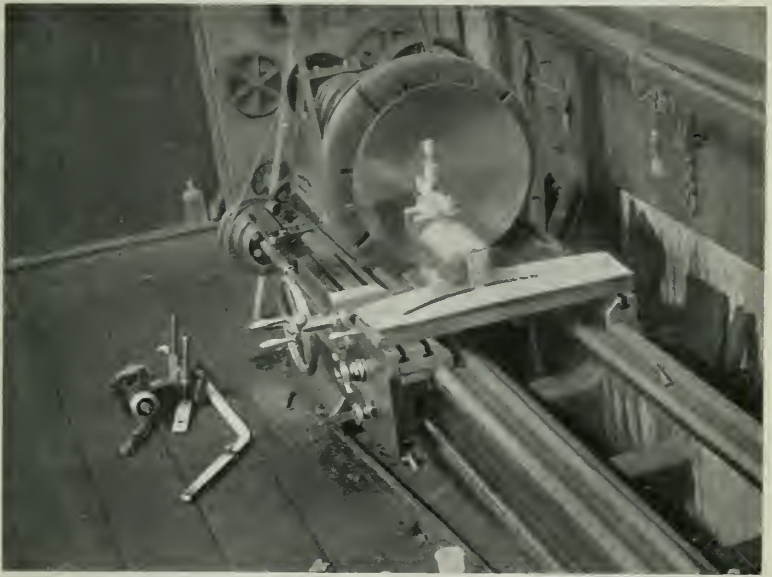
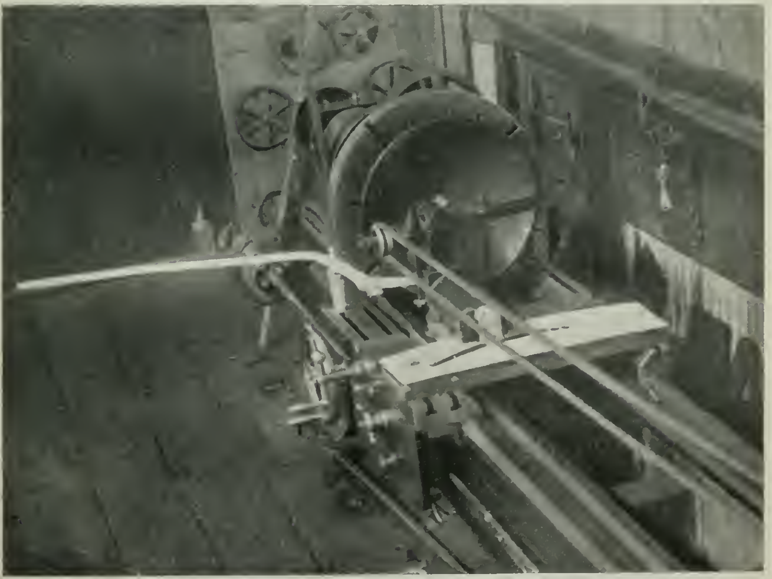


Fig. 2. *Buffing Gear.*



TJ
1
I4
1902
pt.1-2

~~Physical &~~
~~Applied Sci.~~
~~Serials~~

Engineering

Institution of Mechanical
Engineers, London
Proceedings

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE